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# THE PHYSIOLOGICAL ASPECT OF MAJOR ELEMENT NUTRITION ON THE MATURITY OF FLUE-CURED TOBACCO[1]

E. T. McEvoy[2]

*Experimental Farms Service, Ottawa, Canada*

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## INTRODUCTION

Many experimenters have clearly demonstrated the prime importance of an adequate and balanced supply of the major nutrient elements in the production of tobacco and the extreme sensitivity of tobacco to variations in the supply of mineral nutrients has been commonly observed. The three major fertilizer elements, N, P, and K, have been given extensive consideration in tobacco production. The problem of having an optimum supply of these elements available to the crop throughout the growth period, including the period when the leaf is maturing, is recognized as one of great practical significance, especially in the case of flue-cured tobacco. However, it is manifestly difficult to interpret the data from field plot experiments in terms of individual elements. For this reason, solution cultures have been employed in the study of certain problems relating to tobacco nutrition.

An investigation of the optimum nutrition of flue-cured tobacco in sand culture was reported in a previous paper (1). The present work on flue-cured tobacco was designed to study the effects on growth and on nitrogen and mineral composition of the plant produced by variations in the supply of N, P, and K during the period of maturity.

## METHODS

White Mammoth, a variety of flue-cured tobacco, was used in this experiment. The seedlings were grown for eight weeks in sand in 3-inch pots and all were supplied with a complete nutrient solution, developed previously (1), in which all the nutrients were at an optimum concentration for best growth of tobacco. This solution was made up from pure chemicals, giving the concentration of nutrient elements shown in treatment 1, Table 1. Then the seedlings were transplanted to 3-gallon jars, each holding forty pounds of washed sand. One plant was grown in each jar and the nutrient solution was supplied by the constant flow method, one litre per day being supplied to each plant.

The complete nutrient solution was supplied to 48 plants until the plants were topped. This solution contained Ca at a concentration of 240 p.p.m.; Mg, 68 p.p.m.; K, 195 p.p.m.; N, 168 p.p.m.; S, 90 p.p.m.; and P, 155 p.p.m. The concentration of each element was within the

[1] Contribution from the Tobacco Division, Experimental Farms Service, Canada Department of Agriculture, Ottawa, Canada.

[2] Agricultural Research Officer.

optimum range for growth as determined by previous studies (1). In addition, the minor elements B, Mn, and Zn, were supplied at the rate of 0.5 p.p.m. and Fe at the rate of 3.0 p.p.m. This is the number one solution in Table 1.

After topping, 6 plants were harvested and the remaining plants were separated into 7 groups of 6 plants each. Each group was supplied with a different nutrient solution. The complete solution was continued in treatment 1. In treatments 2 to 7, inclusive, the concentrations of N, P, and K were separately reduced to $\frac{1}{2}$ and 0 as compared to the levels of these elements in the complete solution. In these treatments, the concentrations of Ca and Mg, as well as the minor elements, were maintained at the same levels as in treatment 1. The treatments and the quantities of the salts used are listed in Table 1.

During the course of the treatments, notes were taken on the relative maturity of the plants. The onset of maturity is indicated by a dull, yellowish green cast on the lower leaves. As maturity progresses, the yellow colour becomes more intense and advances upward to higher leaves.

Half the plants in each treatment were harvested at the end of 2-weeks' treatment and the remaining plants were harvested at the end of 4-weeks' treatment. The plants were harvested by cutting the stalks off at the base. Fresh weights were recorded for 3 fractions of the plant tissue, namely, the top leaves, the bottom leaves, and the stalk. Each fraction was diced and thoroughly mixed, and aliquots were weighed out for dry-weight determinations and for chemical analyses.

TABLE I.—STOCK SOLUTIONS REQUIRED TO PRODUCE ONE LITRE OF NUTRIENT SOLUTION

| Treat. No. | Treatments | 0.5M $Ca(NO_3)_2$ | 0.5M $KH_2PO_4$ | 0.5M $MgSO_4$ | 0.1M $CaSO_4$ | 0.5M $KNO_3$ | 0.5M $NaH_2PO_4$ | 0.5M $CaCl_2$ | 0.5M $K_2SO_4$ |
|---|---|---|---|---|---|---|---|---|---|
| | | cc. | cc. | cc. | cc. | cc. | cc. | cc. | cc. |
| 1 | All elements | 12.0 | 10.1 | 5.6 | — | — | — | — | — |
| 2 | $\frac{1}{2}$ N | 6.0 | 10.1 | 5.6 | 30.0 | — | — | — | — |
| 3 | 0 N | — | 10.1 | 5.6 | 30.0 | — | — | 6.0 | — |
| 4 | $\frac{1}{2}$ P | 12.0 | 5.0 | 5.6 | — | — | — | — | 2.5 |
| 5 | 0 P | 10.0 | — | 5.6 | — | 4.0 | — | 2.0 | 2.9 |
| 6 | $\frac{1}{2}$ K | 12.0 | 5.0 | 5.6 | — | — | 5.0 | — | — |
| 7 | 0 K | 12.0 | — | 5.6 | — | — | 10.1 | — | — |

The methods used in the chemical analyses were the official methods of the A.O.A.C. (2) with one exception—total nitrogen was determined by the method of Pucher *et al.* (3).

## RESULTS AND DISCUSSION

The growth data are presented in Table 2. An analysis of variance was performed on the total fresh weight data and the least difference between means necessary for significance is appended to the table. The treatments were sources of significant variation at the 5 per cent level. The treatments also had a marked influence on the rate of maturity of the leaves.

Both the ½-N and the zero-N treatments resulted in significant reductions in fresh-weight yield but in increases in the percentage dry weight at the end of both two weeks and four weeks. The zero-N plants did not make any significant gain in weight over the plants harvested before the treatments were started. High nitrogen supply delayed maturity; and, conversely, low nitrogen supply and zero nitrogen hastened maturity. The plants in treatments 2 and 3 in which nitrogen was low and absent, respectively, ripened earlier than did the plants in the other treatments. These differences in the rate of maturity were manifested at the end of two weeks' treatment. Nitrogen-deficiency symptoms—yellowing of the lower leaves and an upright appearance of the top leaves—were evident in a moderate degree after four weeks in the ½-N treatment, but they appeared in two weeks and became severe in four weeks in the zero-N treatment.

The ½-P and zero-P treatments resulted in such slight reductions in fresh-weight yield as not to be significant. However, the reduction in yield produced by the zero-P treatment in four weeks closely approached the level of significance. The effect of phosphorus on the ripening process was indicated by slightly retarded maturity of the leaves after four weeks in treatments 4 and 5 in which the supply of P was reduced to ½ and 0, respectively.

The yield produced by each of the ½-K and the zero-K treatments, with the exception of the former for four weeks, was significantly lower than that of the check. Reduced K supply retarded the rate of maturity less than did reduced P but a deficiency of K seriously interfered with the normal development of the plants. Potassium-deficiency symptoms were manifested by the zero-K plants in 3 weeks and by the ½-K plants in 4 weeks.

The chemical analytical results are presented in Tables 3 and 4. The data on the analyses of the plants for N, P, K, Ca, Mg, and S, reported as percentage of the dry weight of the samples of ground tissue, are the averages of closely-agreeing duplicate analyses. The data representing the concentration in the plant tissues of the six elements studied are given in Table 3 for the samples collected after 2-weeks' treatment, and in Table 4 for the samples collected after 4-weeks' treatment.

Fron a study of the data in Tables 2 and 3, it is evident that a reduction in the supply of nitrogen in the nutrient solution had a marked influence on the accumulation of nutrient elements in the plant tissues. A reduction in the supply of nitrogen resulted in a reduction in the content of nitrogen in all three fractions of the tissue (top leaves, bottom leaves, and stalk) after both 2- and 4-weeks' treatments. The nitrogen content was highest in the top leaves, lower in the bottom leaves and lowest in the stalk. The data for Mg, K, Ca, and S show the same type of direct relationship between the nitrogen supply in the nutrient solution and the concentration of each of these elements in the tissues. However, reduced N supply was associated with an increase in the content of P in the top leaves.

Variations in the supply of phosphorus also influenced the accumulation of nutrient elements in the plant tissue. A reduction in the supply of phosphorus was generally associated with a slight reduction in the content of nitrogen in all three fractions of the tissue after both 2- and 4-weeks'

TABLE 2.—YIELD DATA OF PLANTS HARVESTED TWO WEEKS AND FOUR WEEKS AFTER COMMENCEMENT OF TREATMENTS, RESPECTIVELY

| Treatment No. | Treatment | After two weeks' treatment | | | | After four weeks' treatment | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Average fresh weight | | | | Average fresh weight | | | |
| | | Top leaves | Bottom leaves | Stalk | Total | Top leaves | Bottom leaves | Stalk | Total |
| | | gm. | gm. | gm. | gm. | gm. | gm. | gm. | gm. |
| 1 | All elements | 289 | 410 | 379 | 1078 | 308 | 439 | 425 | 1172 |
| 2 | ½ N | 240 | 338 | 342 | 920 | 272 | 379 | 408 | 1059 |
| 3 | 0 N | 189 | 348 | 326 | 863 | 221 | 319 | 369 | 909 |
| 4 | ½ P | 259 | 408 | 374 | 1041 | 307 | 419 | 438 | 1164 |
| 5 | 0 P | 287 | 405 | 382 | 1075 | 312 | 380 | 425 | 1117 |
| 6 | ½ K | 275 | 342 | 372 | 989 | 240 | 463 | 414 | 1117 |
| 7 | 0 K | 262 | 389 | 369 | 1020 | 268 | 427 | 399 | 1094 |
| All elements, harvested before treatments started | | 197 | 335 | 324 | 856 | — | — | — | — |
| Difference necessary for significance (P = 0.05) | | | | | 52.6 | — | — | — | 57.2 |

TABLE 3.—SUMMARY OF THE MINERAL ANALYSES OF TOP LEAVES, BOTTOM LEAVES, AND STALK TISSUE EXPRESSED AS PER CENT OF DRY WEIGHT, AFTER TWO-WEEKS' TREATMENT

| Treatment No. | Treatment | Top leaves | | | | | | Bottom leaves | | | | | | Stalk | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | P | K | Ca | Mg | S | N | P | K | Ca | Mg | S | N | P | K | Ca | Mg | S |
| 1 | All elements | 2.95 | 0.55 | 3.93 | 2.04 | 0.98 | 0.81 | 1.87 | 0.62 | 2.68 | 3.33 | 0.93 | 0.77 | 1.35 | 0.39 | 3.04 | 0.90 | 0.31 | 0.52 |
| 2 | ½ N | 2.48 | 0.61 | 3.41 | 1.98 | 0.89 | 0.72 | 1.83 | 0.59 | 2.25 | 3.05 | 0.90 | 0.72 | 1.09 | 0.36 | 2.49 | 0.83 | 0.29 | 0.39 |
| 3 | 0 N | 2.06 | 0.64 | 2.62 | 1.76 | 0.74 | 0.62 | 1.18 | 0.55 | 1.94 | 2.42 | 0.81 | 0.50 | 0.93 | 0.33 | 2.30 | 0.75 | 0.26 | 0.41 |
| 4 | ½ P | 2.93 | 0.52 | 3.44 | 1.98 | 0.49 | 0.65 | 1.71 | 0.53 | 3.01 | 2.76 | 0.78 | 0.61 | 1.26 | 0.28 | 4.98 | 0.92 | 0.25 | 0.29 |
| 5 | 0 P | 2.70 | 0.53 | 3.02 | 2.13 | 0.69 | 0.67 | 1.78 | 0.48 | 2.71 | 2.80 | 0.84 | 0.69 | 1.30 | 0.34 | 4.68 | 0.77 | 0.24 | 0.26 |
| 6 | ½ K | 2.47 | 0.45 | 3.50 | 1.96 | 0.47 | 0.71 | 1.78 | 0.35 | 2.41 | 2.36 | 0.67 | 0.84 | 1.17 | 0.35 | 1.60 | 1.00 | 0.30 | 0.30 |
| 7 | 0 K | 2.81 | 0.52 | 2.71 | 2.11 | 0.74 | 0.65 | 1.62 | 0.41 | 2.25 | 2.49 | 0.72 | 0.54 | 1.22 | 0.29 | 1.29 | 1.35 | 0.26 | 0.27 |
| All elements, harvested before treatments started | | 3.98 | 0.75 | 4.14 | 2.22 | 0.65 | 0.63 | 3.20 | 0.89 | 5.02 | 4.01 | 1.08 | 1.18 | | | | | | |

TABLE 4.—SUMMARY OF THE MINERAL ANALYSES OF TOP LEAVES, BOTTOM LEAVES, AND STALK TISSUE EXPRESSED AS PER CENT DRY WEIGHT, AFTER FOUR-WEEKS' TREATMENT

| Treatment No. | Treatment | N | P | K | Ca | Mg | S | N | P | K | Ca | Mg | S | N | P | K | Ca | Mg | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | All elements | 2.37 | 0.41 | 2.09 | 1.57 | 0.44 | 0.84 | 1.59 | 0.45 | 2.40 | 2.70 | 0.83 | 0.68 | 1.33 | 0.37 | 2.24 | 0.83 | 0.41 | 0.23 |
| 2 | ½ N | 1.77 | 0.60 | 1.89 | 1.49 | 0.38 | 0.54 | 1.08 | 0.52 | 1.88 | 2.36 | 0.75 | 0.65 | 1.15 | 0.32 | 2.22 | 0.75 | 0.37 | 0.15 |
| 3 | 0 N | 1.31 | 0.54 | 1.83 | 1.47 | 0.34 | 0.55 | 0.81 | 0.51 | 1.73 | 2.39 | 0.68 | 0.59 | 0.75 | 0.15 | 0.70 | 0.68 | 0.25 | 0.11 |
| 4 | ½ P | 2.34 | 0.43 | 2.12 | 1.91 | 0.37 | 0.67 | 1.42 | 0.41 | 2.24 | 2.61 | 0.64 | 0.63 | 1.17 | 0.31 | 1.54 | 0.94 | 0.30 | 0.22 |
| 5 | 0 P | 2.25 | 0.35 | 2.13 | 1.64 | 0.36 | 0.79 | 1.44 | 0.34 | 1.58 | 2.45 | 0.63 | 0.58 | 1.15 | 0.26 | 1.46 | 0.96 | 0.25 | 0.15 |
| 6 | ½ K | 2.59 | 0.38 | 1.64 | 2.10 | 0.19 | 0.73 | 1.54 | 0.38 | 1.13 | 2.44 | 0.65 | 0.53 | 1.18 | 0.28 | 0.92 | 0.92 | 0.32 | 0.26 |
| 7 | 0 K | 2.14 | 0.43 | 0.79 | 2.05 | 0.43 | 0.58 | 1.58 | 0.41 | 0.78 | 2.64 | 0.72 | 0.68 | 1.10 | 0.26 | 0.55 | 0.75 | 0.32 | 0.38 |
| All elements, harvested before treatments started | | 3.98 | 0.75 | 4.14 | 2.22 | 0.65 | 0.63 | 3.20 | 0.89 | 5.02 | 4.01 | 1.08 | 1.18 | | | | | | |

treatments. The magnesium content of all three fractions of the tissue decreased with reduced phosphorus supply after both two and four weeks. There was no significant reduction in the content of phosphorus in the top leaves until the phosphorus supply was reduced to zero for four weeks. In both the bottom leaves and the stalk, the content of phosphorus was reduced by a reduction in the supply of this element after both 2 and 4 weeks. The content of each of calcium, potassium, and sulphur showed no definite relationship to variations in the supply of phosphorus.

A reduction in the supply of potassium resulted in a decrease in the accumulation of this element in all three fractions of the plant tissue after both 2 and 4 weeks. Otherwise, variations in the concentration of potassium in the nutrient solution did not bear any consistent relationship to the content of nutrient elements in the plant.

The results of this experiment indicate that when tobacco plants of the flue-cured type have been adequately supplied with available nutrient elements until topping time, there is sufficient reserve phosphorus in the plant to support normal growth throughout the ripening period. This shows that sufficient phosphorus can be absorbed by the plant before topping time to satisfy all subsequent needs for this element for leaf production. However, it was further indicated that the reserve of phosphorus in the plant at topping time may be inadequate to promote normal ripening of the leaves.

While these results give evidence that phosphorus is an important element affecting the maturity of flue-cured tobacco, it was shown that nitrogen is the most critical element determining the rate of maturity and leaf growth after topping. In contrast to phosphorus, a low supply or absence of nitrogen in the nutrient solution was manifested by visible symptoms in a comparatively short time. The reserve nitrogen in the plant was low compared to the amount required for normal growth and the lack of this element was soon reflected in abnormal leaf colour and growth.

The plant's reserve of potassium at topping time was apparently adequate to support normal metabolism without visible detrimental effect for two weeks but not for four weeks. It was shown that the requirement of the plant for potassium is high even after topping, at which time a deficiency of potassium retards maturity. Therefore, a liberal supply of potassium is required for the normal ripening of the leaves.

## SUMMARY

The effect of nitrogen, phosphorus and potassium on the maturity and composition of flue-cured tobacco were studied. The plants were grown in sand culture and, until they were topped, they were supplied with a complete nutrient solution in which the nutrients used were within the optimum range for growth of tobacco. After the plants were topped, a series of nutrient solutions was used in which the supply of each of the three nutrients being tested was separately reduced to one-half the maximum, and zero, respectively. The complete nutrient solution was continued in one treatment as a check.

The nutrient treatments during the ripening period were sources of significant variation in fresh-weight yield. The stipulated reductions in the supply of each of N and K, but not P, resulted in reduced yields.

The variations in the supply of the nutrients had a marked effect on the rate of maturity of the leaves. Maturity was accelerated by reduced N supply but was delayed appreciably by reduced P and in lesser degree by reduced K.

At the time of topping, the reserve of each of N and K in the plant was inadequate to support normal growth for the remainder of the growing period. However, the reserve phosphorus at topping time was sufficient to support normal growth but not to promote normal ripening of the leaf.

A decrease in the concentration of N in the nutrient solution was associated with a decrease in the content of each of N, K, Mg, Ca and S in the plant tissues. A decrease in the P supply was associated with a decrease in the content of each of P, N, and Mg in the tissues. A decrease in the K supply was associated with a decrease in the content of K in the tissues but otherwise was unrelated to the content of nutrient ions in the tissues.

## REFERENCES

1. McEvoy, E. T. Studies on the optimum nutrition of flue-cured tobacco. Sci. Agr. 25 : 489-498. 1945.
2. Official and tentative methods of analysis of the association of official agricultural chemists. 1940.
3. Pucher, G. W., C. S. Leavenworth, and H. B. Vickery. Determination of total nitrogen of plant extracts in the presence of nitrates. Jour. Ind. and Eng. Chem. Anal. Ed. 2 : 191. 1930.

# THE EFFECT OF WASTE SULPHITE LIQUOR SOLIDS ON THE CHEMICAL AND PHYSICAL PROPERTIES OF SOIL[1]

F. J. SOWDEN[2] AND H. J. ATKINSON[3]

*Division of Chemistry, Science Service, Ottawa, Canada*

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In a previous paper (11), the authors reported the results of some greenhouse experiments on the effect of the addition of waste sulphite liquor solids on the yields of oats and alfalfa and described the materials used. No significant effect on yields was noted except when the material had an appreciable nitrogen content. It was observed at that time, however, that the waste sulphite material had some effect on the appearance and mechanical behaviour of the soil and it seemed desirable to test the effect of repeated additions of relatively large amounts of this material to soil on its physical and chemical properties.

## PROCEDURE

The soils used were an Uplands sand and a North Gower clay loam. Samples of these soils were passed through a 2 mm. screen and six 2 kg. samples of each soil were weighed into ½ gal. porcelain pots. The experiment was set up as follows:

| Soil type | Pot No. | Amendment | Weight of amendment |
|---|---|---|---|
| Uplands sand | 1 and 2 | Check | — |
| Uplands sand | 3 and 4 | W.S.L.S. Ca-Base | 20 gm.* |
| Uplands sand | 5 and 6 | Manure | 20 gm.* |
| North Gower clay loam | 7 and 8 | Check | — |
| North Gower clay loam | 9 and 10 | W.S.L.S. Ca-Base | 20 gm.* |
| North Gower clay loam | 11 and 12 | Manure | 20 gm.* |

* Equivalent to 10 tons per acre.

The waste sulphite liquor solids (W.S.L.S.) were from a Ca-base cook neutralized with $Ca(OH)_2$. The manure, applied in dried pulverized form, was used so that the effect of the W.S.L.S. treatment could be compared with that of another organic material. Each treatment was thoroughly mixed with the soil which was then brought to 60 per cent moisture-holding capacity. The pots were kept at room temperature and the moisture content of the soil was maintained by weekly additions of water. The experiment was started in January, 1947. In October the soils were removed from the pots, dried at room temperature and passed through a 2 mm. screen. The amendments were added in the same amount as before and mixed with the soils which were again brought to 60 per cent moisture-holding capacity. The soils were dried, sieved and treated with additional amendments again in May, 1948 and January, 1949. The experiment was terminated in October, 1949 and samples were prepared for chemical and physical analysis.

[1] Scientific Contribution No. 191, Division of Chemistry, Science Service, Canada Department of Agriculture, Ottawa, Canada.

[2] Associate Chemist, Division of Chemistry.

[3] Head, Soil Chemistry Unit, Division of Chemistry.

*Methods of Analysis*

The pH, moisture, loss on ignition and total carbon analyses were made by the standard methods used in this laboratory (4). The uronic carbon was determined by the method of Bartholomew and Norman (1). In the lignin determination, the samples were extracted with 1 : 2 ethanol-benzene for 30 hours, refluxed with boiling water for 3 hours, then refluxed with boiling 2 per cent HCl for three hours, dried, ground to pass a 100-mesh screen and the lignin finally determined by the Ross-Hill-Potter (9, 10) method as modified for soils by DeLong and Coldwell (5). Aliquots from the ethanol-benzene, hot water, and HCl treatments were evaporated to dryness at 100° C., ignited at 600° C. and the per cent loss on ignition calculated. The physical analyses were made in the Swift Current soil research laboratory, the water-stable aggregates being determined by the method of Bouyoucos (2) modified by wetting the air dried soil under a partial vacuum of 70 cm. Hg, and the moisture equivalents by the method of Briggs and McLane (3).

## RESULTS AND DISCUSSION

When the soils were dried it was noted that the W.S.L.S. treatment had a marked effect on the physical condition of the sand. This soil was darker in colour and, when dry, formed much harder lumps than did the manure-treated or untreated samples. This effect was much less apparent with the clay.

*Effect on pH*

The pH of the original Uplands sand was 5.5, and that of the North Gower clay loam 7.0. The pH values of the treated samples were determined in December, 1947, May, 1948 and at the termination of the experiment. The results, reported in Table 1, show that, while the pH of the check samples decreased somewhat, that of the soils which received the W.S.L.S. treatment decreased to a considerably greater extent with both

TABLE 1.—pH CHANGES ON TREATMENT WITH THE WASTE SULPHITE MATERIAL AND MANURE

| Soil | Treatment | Pot No. | Dec./47 | May/48 | Oct./49 |
|---|---|---|---|---|---|
| Uplands sand | Check | 1 | 5.2 | 5.0 | 4.8 |
| | | 2 | 5.4 | 5.0 | 4.9 |
| | W.S.L.S. | 3 | 5.0 | 4.5 | 4.3 |
| | | 4 | 5.0 | 4.7 | 4.4 |
| | Manure | 5 | 6.9 | 6.6 | 7.0 |
| | | 6 | 6.9 | 6.7 | 7.1 |
| North Gower clay loam | Check | 7 | 6 8 | 6.7 | 6.5 |
| | | 8 | 7.0 | 6.8 | 6.6 |
| | W.S.L.S. | 9 | 6.4 | 6.2 | 5.5 |
| | | 10 | 6.7 | 6.6 | 5.6 |
| | Manure | 11 | 7.5 | 7.2 | 7.2 |
| | | 12 | 7.5 | 7.2 | 7.2 |

the sand and the clay soils. The application of manure raised the pH especially with the sand soil. The rather significant increase in acidity caused by the addition of W.S.L.S. may be the result of several factors. Although analyses of typical waste sulphite material (8) have shown that it contains organic acids, some of these may be lost on drying. However, the sulphur dioxide, either as "free $SO_2$" or "loosely bound $SO_2$", may contribute to the acidity of the soil and as lignin sulphonic acids decompose the sulphone-sulphur may be released as sulphurous acid.

*Effect on Organic Matter Content*

Table 2 shows the effect of the additions of W.S.L.S. on the moisture, loss on ignition and total and uronic carbon contents of the soil. The percentage moisture was determined after the samples had been air-dried in the laboratory. The addition of organic matter evidently increased the amount of moisture the soils would retain when in contact with the air. The percentage increase was much greater for the sand than for the clay and the waste sulphite material increased the water-retaining power of the soil more than did the manure.

The data for loss on ignition and for total carbon show much the same effect. There was a considerable increase in the organic matter content of the soil with the W.S.L.S. giving a greater increase than the manure. In the case of the uronic carbon, the waste sulphite treatment resulted in a slight increase for the sandy soil but gave no increase with the clay soil. However, the manure increased the uronic carbon content of both soils.

*Effect on Content of Lignin and Extractives*

Table 3 shows the effect of the treatments on the percentages of extractives and of lignin. There seemed to be little effect of treatment on the percentage of ethanol-benzene extractives in the soil from any of the

TABLE 2.—ANALYSIS OF SOILS AFTER FOUR TREATMENTS WITH THE WASTE SULPHITE MATERIAL AND MANURE

(As per cent of air-dry soil)

| Soil | Treatment | Pot No. | Moisture | Loss on ignition | Total carbon | Uronic carbon |
|---|---|---|---|---|---|---|
| Uplands sand | Check | 1 | 0.54 | 1.60 | 0.65 | 0.16 |
| | | 2 | 0.57 | 1.86 | 0.57 | 0.14 |
| | W.S.L.S. | 3 | 1.16 | 3.67 | 1.89 | 0.24 |
| | | 4 | 1.28 | 4.14 | 1.87 | 0.21 |
| | Manure | 5 | 0.90 | 3.28 | 1.56 | 0.31 |
| | | 6 | 0.93 | 3.00 | 1.52 | 0.30 |
| North Gower clay loam | Check | 7 | 3.60 | 7.85 | 3.24 | 0.69 |
| | | 8 | 3.53 | 7.44 | 3.32 | 0.74 |
| | W.S.L.S. | 9 | 4.76 | 9.16 | 4.11 | 0.72 |
| | | 10 | 4.71 | 8.96 | 4.11 | 0.68 |
| | Manure | 11 | 3.76 | 8.78 | 3.99 | 0.85 |
| | | 12 | 3.37 | 8.69 | 3.87 | 0.95 |

pots. There was, however, a slight relative increase in the water-soluble fraction of the organic material in the manure treated soils and a large relative increase in the W.S.L.S. treated soils. With the latter, the increase was relatively much greater for the sand than for the clay. This difference in the effect of the W.S.L.S. on the sand and the clay soil suggests that either there was a greater transformation of the material to a water-insoluble form in the clay soil or the organic matter was adsorbed more strongly on it, since, when applied to the soil, the W.S.L.S. was entirely water-soluble. The results for the 2 per cent HCl extractives are much too high (compare column 3, Table 2 with column 4, Table 3) probably due to incomplete drying of the rather large amount of salts in this extract. Hence, definite conclusions cannot be drawn from them although they seem to show that there were no sharp differences in the amount of this fraction present in the soil as a result of treatment. There was also little effect on the amount of residue left after extraction; this was perhaps to be expected since the residue was largely mineral material and the effect of changes in the organic constituents might not be noticeable.

The method used for the determination of lignin has been criticized (12) but since, by its use, the lignin is first dissolved free from the mineral material and then precipitated and weighed, it would seem superior to methods that depend on determining lignin by difference or by other indirect means of estimation. The data show a slight increase in the lignin content of the clay soil treated with W.S.L.S. and in both soils treated with manure. Since the increase in organic material on treatment was found in the water-soluble fraction (Table 3) and not in the lignin fraction, it would appear that the lignin of the W.S.L.S. did not revert to a water-insoluble material to any great degree.

TABLE 3.—PERCENTAGE OF LIGNIN AND EXTRACTIVES IN SOIL AFTER FOUR TREATMENTS WITH THE WASTE SULPHITE MATERIAL AND MANURE

(As per cent of air-dry soil)

| Soil | Treatment | Pot No. | Organic matter soluble in | | | Residue after extraction | Lignin |
|---|---|---|---|---|---|---|---|
| | | | Ethanol-benzene | Water | Two per cent HCl | | |
| Uplands sand | Check | 1 | 0.16 | 0.20 | 3.12 | 92 | 0.19 |
| | | 2 | 0.24 | 0.24 | 3.24 | 91 | 0.22 |
| | W.S.L.S. | 3 | 0.20 | 0.94 | 3.67 | 90 | 0.17 |
| | | 4 | 0.20 | 1.02 | 4.28 | 91 | 0.25 |
| | Manure | 5 | 0.49 | 0.26 | 3.98 | 91 | 0.42 |
| | | 6 | 0.24 | 0.43 | 3.45 | 92 | 0.35 |
| North Gower clay loam | Check | 7 | 0.48 | 0.56 | 10.11 | 81 | 0.32 |
| | | 8 | 0.45 | 0.68 | 9.52 | 81 | 0.40 |
| | W.S.L.S. | 9 | 0.44 | 0.98 | 8.81 | 80 | 0.49 |
| | | 10 | 0.43 | 0.85 | 8.91 | 78 | 0.56 |
| | Manure | 11 | 0.44 | 0.74 | 9.04 | 80 | 1.18 |
| | | 12 | 0.55 | 0.64 | 8.95 | 80 | 1.04 |

TABLE 4.—WATER-STABLE AGGREGATES IN SOILS AFTER FOUR TREATMENTS WITH THE WASTE SULPHITE MATERIAL AND MANURE

(As per cent of air-dry soil)

| Soil | Treatment | > 2 mm. | 2.0–0.83 | 0.83–0.42 | 0.42–0.25 | 0.25–0.05 | 0.05–0.02< | 0.02 mm. |
|---|---|---|---|---|---|---|---|---|
| Uplands sand | Check | 0 | 3.9 | 9.8 | 31.5 | 47.3 | 4.0 | 3.5 |
| | W.S.L.S. | 0 | 7.9 | 23.8 | 38.0 | 27.4 | 0.5 | 2.4 |
| | Manure | 0 | 3.0 | 7.8 | 32.5 | 50.0 | 3.0 | 3.7 |
| North Gower clay loam | Check | 0 | 11.7 | 13.8 | 11.0 | 28.1 | 23.0 | 12.4 |
| | W.S.L.S. | 0 | 25.1 | 15.3 | 12.9 | 28.9 | 13.0 | 4.8 |
| | Manure | 0 | 11.6 | 15.2 | 12.2 | 30.4 | 20.0 | 10.6 |

*Effect on Physical Characteristics*

The percentages of the various sizes of water-stable aggregates are given in Table 4. The data show that the addition of waste sulphite material resulted in a sharp increase in the percentage of water-stable aggregates of larger size (2.0 – 0.42 mm.) in both soils. This would indicate an increased resistance to wind erosion and possibly a greater rate of water infiltration (6). It has been suggested (7) that polysaccharides formed by soil bacteria, especially those containing a relatively large percentage of uronic acids, play an important role in aggregate formation in soils. It might be expected that some of these compounds would be formed by bacteria from the sugars present in the waste sulphite solids. Apparently the increase in water-stable aggregates noted above was not the result of the formation of polyuronides since in that event the manure treated soils should have had the more stable structure (Table 2). The data recorded in Table 3 indicate that soil lignin did not function as an aggregate forming material or it would have had a greater effect in the manure-treated soil. The effect of the waste sulphite liquor solids in aggregation, therefore would seem to be a direct one; that is, some component of the material itself was responsible for aggregate formation rather than a compound formed from it by chemical or bacterial action. This conclusion is strengthened by the fact that the amount of water-soluble material was greatest in the waste sulphite liquor solids treated soils.

Table 5 records the moisture equivalent data and shows that the treatments had little effect on this characteristic in the clay soil while they had considerable effect in the sand soil, the W.S.L.S. having a greater influence than the manure. An increase was to be expected in view of the increase in organic matter as a result of treatment. This increase was greater in the case of the sandy soil. The effect of the organic matter in the clay soil on moisture equivalent would be somewhat masked by the moisture-holding power of the clay.

TABLE 5.—MOISTURE EQUIVALENT OF SOILS AFTER FOUR TREATMENTS WITH THE WASTE SULPHITE MATERIAL AND MANURE

| Soil | Treatment | Per cent |
|---|---|---|
| Uplands sand | Check | 5.9 |
| | W.S.L.S. | 9.7 |
| | Manure | 8.1 |
| North Gower clay loam | Check | 26.6 |
| | W.S.L.S. | 28.0 |
| | Manure | 27.9 |

## SUMMARY

A laboratory experiment was conducted to determine the effect of repeated additions of waste sulphite liquor solids and manure on the chemical and physical properties of a clay and a sandy soil. Four applications of each treatment were made over a period of two years.

The W.S.L.S. treatment decreased the pH while the manure treatment increased it. There was an increase in the content of organic carbon and loss on ignition percentage by both treatments. The manure treatment increased the uronic carbon and lignin content of both soils, whereas the W.S.L.S. had a lesser effect on these constituents. The organic fraction which was most affected by the addition of W.S.L.S. was the fraction soluble in hot water.

The addition of W.S.L.S. increased the size of the water-stable aggregates; this effect seemed to be a direct one and not the result of some compounds formed by bacterial or chemical action.

The moisture equivalent of the sandy soil was increased by both the W.S.L.S. and manure treatments, but there was little effect on this property in the case of the clay soil.



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## REFERENCES


1. Bartholomew, W. V., and A. G. Norman. The determination of uronic groups in soils and plant materials. Iowa State Coll. Jour. Sci. 15 : 253-260. 1941.
2. Bouyoucos, G. J. A method for making mechanical analysis of the ultimate natural structure of soils. Soil Sci. 40 : 481-485. 1935.
3. Briggs, L. J., and J. W. McLane. The moisture equivalent of soils. U.S. Dept. of Agr., Bur. Soils, Bull. 45. 1907.
4. Chemistry Division, Science Service. Chemical methods of soil analysis. 1949.
5. DeLong, W. A., and B. B. Coldwell. *Private communication.* 1949.
6. Doughty, J. L. *Private communication.* 1950.
7. Martin, J. P. Micro-organisms and soil aggregation. II. Influence of bacterial polysaccharides on soil structure. Soil Sci. 61 : 157-166. 1946.
8. Partansky, A. M., and H. K. Benson. Analysis of sulphite waste liquor. Paper Trade Jour. 102, No. 7, 29-35. 1936.
9. Ross, J. H., and A. C. Hill. The determination of lignin by means of formaldehyde and sulphuric acid. Pulp and Paper Mag. of Can. 27 : 541-544. 1929.
10. Ross, J. H., and J. C. Potter. Determination of lignin by means of formaldehyde and sulphuric acid. Pulp and Paper Mag. of Can. 29 : 569-571. 1930.
11. Sowden, F. J., and H. J. Atkinson. Waste sulphite liquor solids as a soil treatmen t Sci. Agr. 28 : 175-182. 1948.
12. Thomas, B., and D. G. Armstrong. A study of some methods at present used for the determination of lignin. J. Agr. Sci. 39 : 335-346. 1949.

# THE ROLE OF ETHYLENE IN FRUIT STORAGE[1]

S. W. Porritt[2]

*Dominion Experimental Station, Summerland, B.C.*

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There is evidence that presence of the gas ethylene in the storage atmosphere tends to accelerate the ripening processes in fruit. It is also known that fruits themselves generate ethylene. These findings have stimulated interest in the commercial possibilities of supplying additional ethylene to the storage atmosphere and conversely removing from the storage the ethylene produced by the fruits. The literature dealing with both aspects of this subject is reviewed in this paper.

The complex metabolic processes of fruit during growth and after abscission produce many compounds, mostly organic both solid and gaseous (12, 68, 36). Included in the gaseous products of metabolism are carbon dioxide, esters of formic, acetic, caproic and caprilic acids, acetaldehyde and ethylene. Of these, ethylene has the most practical significance and has been the subject of much research.

Ethylene is an unsaturated hydrocarbon gas, non-poisonous, with a faint sweetish odour. Its boiling point is $-103.9°$ C. and specific gravity 0.978 compared to air. It is soluble in water to the extent of 25.6 cc. per 100 gm. of water at 0° C.

## EFFECTS OF ETHYLENE ON COLOUR AND RIPENING OF FRUITS AND VEGETABLES

At the beginning of the twentieth century, before ethylene was identified or its presence in fruit vapours suspected, it was observed that citrus fruits coloured abnormally when kerosene heaters were used in rail shipments of fruit to northern markets. Subsequently it was learned that not heat, but a product of incomplete combustion of the kerosene was responsible for the accelerated colouring (70). The citrus industry of California and Arizona adapted this technique for commercial use on a fairly large scale. Following Denny's (9) identification of ethylene as the colouring agent and his patenting of a colouring technique for public use in 1923, kerosene stoves in the colouring rooms were replaced by the use of pure ethylene.

Suitable conditions of gas concentration, temperature and ventilation for colouring citrus fruits were worked out by Chace and Denny (2). As a result of extensive investigation by the California Fruit Growers' Exchange (6) a carefully controlled technique was proposed in which ethylene was used in air-tight colouring rooms on a commercial scale. The optimum conditions for colouring oranges were provided by a constant temperature of 70-80° F., a relative humidity of 80-85 per cent when fruit was being heated and 90-95 per cent when up to temperature, and a concentration of ethylene of 1 cubic foot to every 5,000 cubic feet of air space. Under these conditions colouring was produced in 2 to 5 days. Ventilation of colouring rooms was necessary when carbon dioxide concentration reached 1.0 to 2.0 per cent.

[1] Contribution No. 742, Division of Horticulture, Experimental Farms Service, Canada Department of Agriculture.

[2] Horticulturist, Fruit Harvesting and Storage Investigations, Dominion Experimental Station, Summerland, B.C.

Success is colouring citrus fruits stimulated many investigations into the possible use of ethylene as a ripening agent for other fruits and vegetables. Such workers as Denny (9), Chace (4), Harvey (37), Hibbard (38), Finch (15), Hansen and Hartman (28) reported that ethylene treatment increased the rate of ripening of lemons, oranges, bananas, melons, pears and tomatoes, and hastened blanching of celery and hulling of pecan nuts. Peaches and apricots did not respond satisfactorily to ethylene treatment (1). Chace (4) reported some value in treating a few varieties which did not normally colour uniformly; however, such varieties are grown to only a limited extent.

The literature dealing with ethylene contains many conflicting reports on the effectiveness of ethylene as a ripening agent. Hansen (29), working with pears, found that there was a drift in respiratory activity from minimum to maximum regardless of low or high temperature storage and that the stimulating effect of ethylene was definitely confined to a period prior to maximum respiratory activity. That the response of fruit to ethylene may be limited to a definite period of ontogeny may account for discrepancies in ripening effects from ethylene treatments as reported by different workers.

The accumulation of data on ethylene ripening gradually dispelled the idea that the gas could be used indiscriminately for ripening immature fruits and vegetables and that ethylene-treated products were superior to those ripened normally.

Certain metabolic processes may be accelerated by ethylene. Thus, normal reactions such as destruction of chlorophyll, conversion of starch to sugar, hydrolysis of sucrose to reducing sugars and hydrolysis of protopectin to soluble pectins may be stimulated by ethylene. No changes, however, are produced by ethylene treatment that would not normally occur during the regular course of ripening. Chace and Church (3) showed that ethylene treatment effected no change in the edible portion of citrus fruits. Similar conclusions have been reached in respect to other fruits and vegetables (38).

At the present time California citrus fruits are treated with ethylene to a limited extent and with a much lower concentration than used formerly. Colouring in the peel is stimulated by ethylene at 1 part in 250,000 parts of air at which concentration respiration is reported to be unaffected (57).

Williams (86) reports the use of ethylene in Australia to colour lemons using a concentration of 1 to 2000-5000.

## PHYSIOLOGICAL RESPONSES OF PLANTS TO ETHYLENE

Certain physiological effects of ethylene on plant material were demonstrated as early as 1913 by Harvey (36), who showed that ethylene in concentrations as low as 1 part in 10,000,000 produced epinastic responses in the Castor bean. The effects of a number of different gases and the responses of other kinds of plants were subsequently examined by many investigators. Of 38 gases tested by Crocker *et al.* (7) only ethylene, propylene, acetylene, butylene and carbon monoxide produced characteristic leaf epinasty in tomato plants, and of these gases ethylene was 500 to 500,000 times more effective than the other four.

The following minimum concentrations were required to produce leaf epinasty in tomato plants with a two-day exposure:

| | | |
|---|---|---|
| Ethylene | 1 part in | 10,000,000 |
| Acetylene | 1 part in | 20,000 |
| Propylene | 1 part in | 20,000 |
| Carbon monoxide | 1 part in | 2,000 |
| Butylene | 1 part in | 200 |

These short-chain, unsaturated hydrocarbons may have the effect of either an anaesthetic or stimulant and are of low toxicity to plant tissue. Crocker *et al.* (8) report growth stimulation such as intumescence in stems, roots and lenticels; initiation of root development, and induced elongation sometimes causing epinasty. Depending upon the concentration, ethylene and similar unsaturated gases may increase or depress respiration and reduce or completely inhibit elongation.

## IDENTIFICATION OF ETHYLENE IN RIPE FRUIT EMANATIONS

Observations on the stimulating effect of ripe fruit on unripe fruit (81) followed by Denny's (9) identification of ethylene as the active agent in the kerosene ripening method, supported the theory that ethylene was evolved by ripening fruit. Elmer (11, 12) showed that gases from ripe apples inhibited the sprouting of potatoes. An English worker, Huelin (39), furnished further evidence by demonstrating the similarity of effects of pure ethylene and the volatiles from ripening apples on sprouting potato tubers.

By passing ripe apple vapours through bromine, ozone, fuming nitric acid, fuming sulphuric acid or by combustion over copper oxide, Smith and Gane (71) were able to remove the active material which had adversely affected the growth of pea seedlings, thus indicating the presence of ethylene. Gane (17) showed that of the known substances which inhibited pea seedlings only ethylene produced results in the concentrations found in apple volatiles.

Ethylene in fruit volatiles was first identified using chemical means by Gane in 1934 (16, 17, 18). His technique consisted of passing apple vapours through bromine at $-65°$ C. and heating the oil thus obtained (ethylene dibromide) with aniline to form a substance with the properties of N, N$^1$ diphenylethylene diamine, proving that ethylene was present in the apple vapours.

Biological and chemical evidence of the presence of ethylene in vapours of ripening pears was presented by Hansen and Hartman (27), Gane (22) and Christensen *et al.* (5). Using bromine absorption methods, Niederl *et al.* (63) and Pratt *et al.* (69) chemically identified ethylene in the volatile products of ripening bananas and avocados, respectively. Miller *et al.* (58), using biological methods, demonstrated that ethylene was present in volatile emanations from oranges, tangerines, limes, lemons and grapefruit; and further, that decaying oranges, oranges inoculated with Penicilium digitatum, and pure cultures of Penicilium digitatum also produced ethylene.

Stone fruits also produce a limited amount of ethylene during their brief storage life. Isaac (41) in South Africa showed by epinastic responses of plant material that peaches and plums produced ethylene in amounts too low to be practical for chemical analysis.

With the establishment of chemical proof for the presence of ethylene in fruit vapours, the epinastic response of young plants became an acceptable indicator for low concentrations of ethylene. Using this method, both vegetative and reproductive organs of many species of plants were shown to evolve ethylene during normal metabolic activity. Not only ripe fruits but also immature fruits such as tomato, squash and apple were reported by Denny (10) to yield ethylene. In the same year Kidd and West (48) showed that immature apples produced ethylene.

## RELATION OF ETHYLENE TO RESPIRATION

From the standpoint of storage life of fruit the dominant metabolic activity is respiration. The rate of respiratory activity, as measured by oxygen-carbon dioxide exchange, is an index to the rate of metabolism and hence the length of life of the fruit.

After fruit setting during cell division and enlargement, respiration proceeds at a high level, accompanied by upgrade metabolism in which complex substances are synthesized from simpler substances. As the fruit grows to maturity the respiration rate gradually declines in apple and pear fruit to a minimum at about harvest time. Following this low respiratory level a distinct increase occurs in which the respiratory value may increase several times. Kidd and West (42) termed this respiratory rise to a peak "the climacteric", which is followed by declining respiratory activity with only a slight rise upon breakdown.

Factors which are associated with the rise in respiratory activity appear to be similar to those associated with volatile production. These two functions follow the same general trends throughout the storage life of the fruit; however, the peaks do not always correspond. As fruit matures and ripens, ethylene production increases to a peak, concomitant with the respiratory climacteric and then declines as does the respiratory activity.

The production trends of ethylene and carbon dioxide in apples and bananas are very similar. The ethylene output increases during the respiratory climacteric, declines rapidly, rises again briefly, then subsides slowly during senescence (61). The peak of ethylene production in McIntosh, and several other varieties of apples, lags behind the respiratory peak by about five days at 20° C. (60, 34).

Hansen (32) reports that the ethylene production in pears follows a somewhat different trend to apples and bananas. The peak in ethylene output occurs about the same time as the respiratory peak, and during the senescent decline no further rise occurs to correspond with the brief respiratory rise.

Although ripening and the occurrence of a respiratory climacteric appear to depend upon a supply of ethylene (49, 33) which also increases during this period, the two processes may not be directly correlated. Hansen (32) gives evidence for this in the comparison of carbon dioxide and ethylene production. During the climacteric rise there is a much

greater increase in ethylene than in carbon dioxide production. Varietal differences add further proof. The respiratory activity of Bartlett is double that of Anjou, but the ethylene production in Bartlett is 6 to 7 times as much as in Anjou. Moreover, respiratory activity and ethylene production do not follow the same trend in a range of temperature from 0 to 40° C. At 40° C. the carbon dioxide of respiration is at a maximum while the ethylene is at a minimum.

*Effect of Temperature on Respiration and Volatile Production*

The effects of temperature changes on fruit metabolism, although more complex, are similar to those on other chemical processes. Raising the temperature of fruit increases the respiratory activity, causing a corresponding increase in oxygen-carbon dioxide exchange and decrease in respirable substrate. Raising the temperature also induces a corresponding increase in production of volatile material. Southwick (79) reported 12 times as much volatile evolution from McIntosh at 40° F. as at 32° F., while at 74° F. apples emitted as much organic vapours in one day as in five months at 32° F.

Variations in temperature have different effects on respiration and ethylene production. Hansen (32) found that respiration increases in intensity throughout the range of 0-40° C., while ethylene production showed a similar increase to a maximum at 20° C., but at higher temperatures ethylene formation fell off sharply until at 40° C. production was entirely inhibited. Although carbon dioxide content is high and oxygen content of the tissue is low at this temperature, Hansen offers proof that this is not the factor limiting the production of ethylene.

With increasing storage temperatures up to a maximum at about 80° F., the respiratory peak occurs earlier, the rise becomes higher and more pronounced.

Kidd and West (51) showed that the rise from the preclimacteric minimum in Sturmer Pippin at 1° C. to a maximum, was 40 per cent; at 20° C. it was 100 per cent. Storage temperatures from 1° to 15° C. have only little influence on the time required for preclimacteric apples or pears to reach a minimum activity, i.e., the point prior to the beginning of the climacteric rise (54), but the interval between minimum and maximum in the climacteric is profoundly influenced by temperature. The duration, according to Kidd and West (48), may be 10 times as long as 8° C. as at 22° C. At 1° C. the slow progress of the climacteric rise may extend over a five- to six-month period with some varieties.

While changes of temperature may influence the rate of respiration and the storage life of apples, the total carbon dioxide liberated and the dry matter lost remain approximately the same (44). For example, the storage temperatures of three similar samples were 2.5°, 10°, 22.5° C. and the storage life, respectively was 205, 97, and 45 days. The total carbon dioxide output and dry matter lost was about the same in the three cases.

*The Oxygen Content of Storage Atmosphere*

With low oxygen supply, ethylene production is greatly repressed or entirely inhibited, but carbon dioxide production may continue in either aerobic or anaerobic condition, at least to some extent.

Not only does low oxygen tend to inhibit the production of ethylene, but, according to Kidd and West (46), the ripening effect of ethylene diminishes with reduction of oxygen, until at 0.3 per cent or less the ethylene has no effect on respiration. Thus the principle of "controlled atmosphere storage" or "gas storage", involving low oxygen and relatively high carbon dioxide atmospheres, functions to depress ethylene production and delay the climacteric rise, thus reducing the ripening rate. Storage life of individuals in any one variety under similar storage conditions may vary, being influenced by maturity, size and growing conditions. Coincident with long life is low respiratory activity, small size, prime maturity, and a small and extended climacteric (43).

*Amount of Ethylene Required to Stimulate Respiration and Ripening*

In order for ethylene to stimulate respiration and ripening of fruit in storage ethylene must reach a certain minimum concentration or threshold value (43) and be maintained for a certain period of time. Under normal conditions, once there is a sufficient concentration of ethylene to induce ripening and the climacteric rise, the process is irreversible; there is no recovery. Work by Kidd and West (45), however, indicates that a brief exposure to ethylene may initiate a respiratory rise followed by recovery. As a result, however, the climacteric rise may occur earlier than it would have normally. Apples and pears, even when immature, produce ethylene, which if allowed to accumulate may cause respiratory stimulation. This "auto-stimulation" invariably occurs in apples, but Kidd and West (43) cite instances where early gathered, individually isolated Conference pears have failed to show a climacteric.

According to Hansen (28), the small quantity of ethylene arising from immature Bartlett and Anjou pears, about 1 part in 22 million, produced leaf epinasty but had no effect upon respiration of fruit. Treatment with ethylene at 1 part in 1000, however, caused immediate respiratory stimulation.

Kidd and West (52) found that the onset of the climacteric of individual Rome Beauty apples, while still attached to the tree, varied as much as three months. Picking the fruit, however, hastened the onset of the climacteric. Under normal handling conditions where fruit is placed in bushel boxes or similar containers, the ethylene produced by an individual fruit may be sufficient to stimulate the activity of neighbouring specimens and thus hasten the occurrence of the climacteric of the entire lot.

Very low concentrations of ethylene, 1 part in 250,000 parts of air, accelerate colour change in orange peel without apparent effect on the respiratory processes (57).

Kidd and West (45) have correlated, to some extent, the effects of concentration, exposure and temperature. A 1- to 2-day exposure of apples to ethylene at concentrations of 1 : 500 at 20° C. resulted in an immediate rise in respiration. A similar exposure at 0° C. had no effect, but a 3-day exposure to this concentration at 0° C. produced stimulation. They further demonstrated that brief exposures of unripe apples to ethylene may cause a temporary stimulation of respiration, followed by recovery. As a result, however, the ultimate climacteric occurred earlier than normal.

While the presence of ethylene is associated with the climacteric rise and onset of ripening, unless other conditions are suitable for ripening, ethylene has little effect. For example, very low oxygen or high temperature inhibits ripening, regardless of the presence of ethylene. Hansen (32) suggests that the specific reaction in which ethylene is formed must first occur in order for fruit to ripen.

*Amount of Ethylene Produced*

Ethylene production varies considerably with species and variety. Hansen (32) reported that each pear variety has a characteristic maximum rate of ethylene production which varies but little in different lots. Fidler (13) suggests that apples of the same variety, but grown in different districts, may produce ethylene at different rates. In general, Fidler lists dessert apples such as Cox Orange as producing more volatiles than culinary varieties of the Bramley Seedling class, which incidentally have longer storage life. Nelson (61) and Hansen (34) concluded that varieties of apples with long storage life have less ability to produce ethylene than short life varieties.

That an inverse correlation exists between length of maturing period of apples and the amount of ethylene produced during ripening, is revealed by Hansen's investigations (34). Thus Astrachan and Red June mature early and have a maximum ethylene output of 11 and 9 ml. per kgm. per 24 hr., respectively, while Delicious and Newtown evolve about 1.7 ml. of ethylene for the same period.

Gane (16) estimates the total production of ethylene during the post-harvest life of an apple to be approximately 1 ml. at 20° C. Hansen (34) makes more allowance for varietal differences in his estimation of 1 to 4 ml. of ethylene per bu. per day, depending on variety and the length of time in storage.

Hansen (32, 34) has determined maximum rates of ethylene production at 20° C. for a number of varieties of apples and pears as indicated below:

| *Variety* | *Max. ethylene output, ml./kgm./24 hr.* |
|---|---|
| Astrachan | 11.38 |
| Red June | 9.27 |
| Gravenstein | 5.16 |
| Delicious | 1.78 |
| Newtown | 1.77 |
| Bartlett | 3.25 – 4.48 |
| Anjou | 0.57 – 0.78 |

*Reactions Accompanying the Climacteric*

In apples, as the climacteric progresses accompanied by high ethylene production, the qualities of ripeness develop. Protopectin changes to soluble pectin producing fruit softening, chlorophyll disintegrates and fruit becomes yellow, there is a reduction of acid content and hydrolysis of starch to sugar, sweetness is increased, and various esters are formed giving rise to characteristic aromas.

Pears stored at high temperatures follow a similar trend in which the eating ripe stage may correspond to the peak of the climacteric, but cold stored pears may still be hard at the climacteric peak (50). Hansen and Hartman (23) showed that Bartlett, Comice and Anjou without cold storage were fully ripe before the respiratory peak had been reached; but at cold storage temperatures ripening was delayed till the post-climacteric period or until fruit was placed in a temperature favourable to ripening.

A distinct change in the nitrogen metabolism of ripening fruit also takes place in which protein (alcohol insoluble) nitrogen increases as the climacteric rise progresses in apples and pears (40, 55). The total nitrogen remains approximately at the same level during the storage life.

## THE EFFECT OF RIPE FRUIT VAPOURS ON OTHER FRUIT

Coincident with the use of kerosene stoves for ripening citrus fruits, Cousins in Jamaica, 1910 (81) found that bananas stored with oranges ripened more rapidly than when segregated. The cause was attributed to mixing of different kinds of fruits in storage, a practice which was discontinued without further investigation.

About the same period in the United States the effects of ripe fruit upon green fruit of the same kind were observed in banana shipments from the tropics. Shipping mixed consignments of ripe and green bananas resulted in an abundance of over-ripe fruit reaching its destination. Forced ventilation and later refrigeration were effective in controlling "ship-ripes". Ridley of the United Fruit Company in 1923 demonstrated conclusively that something produced by ripening bananas hastened the ripening of green bananas (81).

Kidd and West (45) produced immediate rise in respiration of pre-climacteric apples by exposing them to vapours of ripe apples.

Gane (18) demonstrated the similarity of pure ethylene and ripe fruit vapours in stimulating the ripening of green bananas.

### *Influence of Maturity and Amount of Fruit on Ripening of Unripe Fruit*

It has been shown that volatiles from ripe apples and pears contain sufficient ethylene to stimulate ripening of exposed unripe fruit (22, 27, 28, 30, 45, 46, 48, 73, 74). However, only pre-climacteric fruit is affected. There seems to be general agreement that pre-climacteric fruit has little or no effect on other pre-climacteric fruit (45, 27, 28, 73, 74), although it has been established that immature, unripe apples and pears produce ethylene (48, 53, 54, 10, 22, 33). Hansen concluded that immature Bartlett and Anjou pears, shortly after picking, produced sufficient ethylene to cause leaf epinasty, but not enough to affect respiration unless the gas was allowed to accumulate. Gane (22), however, was able to stimulate ripening of bananas by gases from immature pears.

Smock (74) brought about immediate respiratory stimulation in pre-climacteric apples by exposure to 1 per cent of their number of post-climacteric apples for 18 to 36 hours. Increasing the number of ripe fruit over 1 per cent had no effect.

It seems apparent that if auto-stimulation occurs there must be sufficient ethylene produced by the pre-climacteric individual to effect a normal climacteric rise in itself.

Early maturing varieties of apples may show a full climacteric rise on the tree, while in late maturing varieties the slow rise is normally not complete before the fruit separates naturally from the tree (56). Following long storage, apples are generally in the post-climacteric phase, but late varieties or gas stored fruit may still be pre-climacteric and subject to ethylene stimulation.

*Influence of Temperature on Response to Ripe Fruit Vapours*

Even at low temperatures (3° C.), a brief exposure of pre-climacteric fruit to ripe fruit gases or ethylene will stimulate the subsequent onset of the climacteric (48). However, once initiated, the slow process of the climacteric in apples and pears in cold storage is not affected by additions of ethylene over that normally produced by the fruit (48, 28).

In general, the lower the storage temperature, the greater may be the exposure to ethylene without consequent stimulation of the climacteric rise (51).

## AIR PURIFICATION

In fruit storages, particularly those containing mixed varieties or fruit in different stages of ripeness, ethylene accumulations may stimulate the ripening of pre-climacteric, unripe fruit. Other gases and odours may accumulate to cause scald or off flavours.

Since ventilation of cold storage rooms is generally impractical, consideration of some method of air purification to remove harmful gases from the storage atmosphere has received increasing attention.

Smock (75) reports Fontanel's claims of success in 1936 from air conditioning with activated carbon to filter out the stimulating gases of ripening fruit, but was unable to support this by his own work in 1943 with activated carbon and other adsorbents and absorbents. Only brominated activated carbon seem to be effective. Further studies by Smock (75), Southwick (79), and Smock and Southwick (76) pointed towards brominated activated carbon as an effective air purifying agent. In 1948 Smock and Southwick's results (77) indicated good scald control resulting from recirculation of the storage atmosphere through activated carbon without bromine. This form of air purification was reported to give about as good scald control as shredded oil paper even in mixed varieties and added about three weeks' storage life to the fruit from a firmness standpoint. Increased storage life was attributed to the removal of ethylene, although this gas was not determined chemically during the test. The use of bromine was discontinued because of corrosion of the filter canister and consequent reduction of air flow.

Phillips (64, 65, 66) at Ottawa reports that activated carbon gave some measure of scald control, but was inferior to oiled wraps. The use of canisters of activated carbon appeared to extend the length of storage life from a quality basis and give good control of storage odours. Reduced softening rates and some reduction in core flush incidence was also attributed to the use of carbon canisters.

Smock (78, 82) also reported successful odour removal in refrigerated storages by use of activated carbon.

Van Doren (83, 84) has tested air purification techniques in commercial storages in Washington using activated coconut shell carbon. His results showed reduced rate of softening and longer storage life of fruit thus treated.

After studying the influence of activated coconut shell carbon filters, Gerhardt (25) concluded that this method of air purification failed to remove ethylene from the storage atmosphere. In test commercial installations activated carbon also failed to reduce the content of volatiles other than ethylene below that found in rooms without air purification, but in small experimental rooms at 35° F. activated carbon did lower the total volatile level to about one-third that in check rooms.

The first picking of Bartlett pears held in purified air showed a superior condition in terms of firmness, soluble pectin and incidence of scald. This difference, however, was not sufficient to improve the dessert quality or extend the period of acceptability for the ripened fruit, Gerhardt (25). Intensity of scald in early harvested Red Delicious was somewhat reduced by the use of carbon filters. However, storage in air purified by passing through activated carbon did not prolong storage life, improve ripening capacity or dessert quality of Red Delicious, Golden Delicious, or Jonathan apples or Anjou pears of early or late maturity.

Since ethylene appeared to be the only constituent of fruit volatiles which would promote ripening, and since circulating storage air through activated carbon filters apparently delays ripening, it has been assumed that ethylene was adsorbed by the carbon. However, analyses of storage atmospheres have failed to show any significant ethylene removal from air circulated through activated carbon canisters (25, 35).

Walls (85) at Ditton Laboratory, Cambridge, found activated carbon in Dorex canisters to be effective as an ethylene adsorber only when cooled to about −40° C. and only when moisture had first been removed.

Hansen (35) reports extended storage life of Anjou pears where activated carbon was used; however, analyses showed that while some volatile esters were adsorbed, the ethylene was not reduced.

Fidler (14) tested the effect of both plain and brominated activated carbon filters for ethylene and odorous volatile removal and the incidence of scald on King Edward VII apples. He reported that while plain activated carbon efficiently reduced the concentration of non-ethylene fractions it did not remove ethylene nor did it reduce scald. Brominated carbon filters provided reasonably good absorption of ethylene, very efficient absorption of the odorous fraction and better scald control than plain carbon. Oiled wraps, however, were superior to either of these mediums in scald control.

Differences in firmness as a result of treatments were barely significant but hardest apples were correlated with the storage atmosphere lowest in ethylene, i.e., where brominated carbon filters were used.

As a result of research at Cornell University, Southwick (80) proposes that ripening gases other than ethylene are produced as apples ripen.

Adsorption of these other ripening gases by carbon filters might account for the extension of storage life regardless of a relatively high ethylene content of the atmosphere.

## METHODS OF ETHYLENE DETERMINATION

Nelson (59) estimated the ethylene content of fruit tissue by oxidation with potassium permanganate after the other volatiles had been removed by passing the gas through sodamide. The extent of reduction of the potassium permanganate was measured with ferrous ammonium sulphate.

The method used by the Department of Pomology, Cornell University, combines an adaptation of the method of Gerhardt and Ezell (23) for estimation of oxidizable volatiles excepting ethylene with the method developed by C. R. Gross for the determination of ethylene.

In this method volatiles other than ethylene are absorbed by concentrated sulphuric acid in a Truog tower and by anhydrous magnesium perchlorate in a succeeding tower. Finally the ethylene is taken up by perchloric acid and mercuric oxide (mercuric perchlorate) in a Truog tower assembly. The ethylene is then oxidized by a perchloratocerate solution and the excess back titrated with sodium oxalate. One ml. of 0.1 N. perchloratocerate is equivalent to 0.3506 gm. ethylene.

Hansen and Christensen (30) describe a method of ethylene analysis in a gas sample. The ethylene in the sample is purified of interfering substances and reacted with bromine liberated from potassium bromate. Potassium iodide is then introduced and the iodine thus liberated is titrated with sodium thiosulphate. One ml. of 0.0025 N. potassium bromate is equivalent to 0.028 ml. of ethylene N.T.P.

Fidler (13) determined ethylene and non-ethylenic fractions of apple volatiles by an adaptation of Walls' (85) method in which concentrated sulphuric acid and sulphuric acid activated with silver sulphate absorbs the ethylene. Potter *et al.* (67) also proved the value of this method as did Gerhardt (24) who used concentrated sulphuric acid plus silver sulphate to absorb ethylene in a method for simultaneous measurement of carbon dioxide and organic volatiles of fruit and vegetable internal atmospheres. In Fidler's method, wet oxidation of ethylene in the activated acid was carried out with a mixture of concentrated sulphuric acid, ortho phosphoric acid, chromium trioxide and copper sulphate. The carbon dioxide evolved was absorbed in KOH solution and the soluble carbonate precipitated as $CO_3$ by the addition of $BaCl_2$.

## REFERENCES

1. Atkinson, F. E., and C. C. Strachan. Ripening of apricots with ethylene. Canada Dept. Ag., Summarized report 1929-1940, Fruit and Vegetable Products Lab., Summerland, pp. 38-39. 1942.
2. Chace, E. M., and F. E. Denny. The use of ethylene in colouring citrus fruits. Indust. & Eng. Chem. 16 : 339-340. 1924.
3. Chace, E. M., and C. G. Church. The effect of ethylene on the composition and colour of fruits. Indust. & Eng. Chem. 19 : 1135-1139. 1927.
4. Chace, E. M. Treating raw canning products with ethylene. Food Industries 3 : 6, 297-298. 1931.
5. Christensen, B. E., E. Hansen, V. H. Cheldelin, and J. B. Stark. The determination of ethylene evolved by apples and pears. Science 89 : 319-321. 1939.
6. Colouring citrus fruits. California Fruit Growers' Exchange, Research and Field Dept. 1932.

## REFERENCES—Continued


7. Crocker, W., P. W. Zimmerman, and A. E. Hitchcock. Ethylene induced epinasty of leaves and the relation of gravity to it. Contributions from Boyce Thompson Inst. 4 : 177-218. 1932.
8. Crocker, W., A. E. Hitchcock, and P. W. Zimmerman. Similarities in the effects of ethylene and plant auxins. Contributions from Boyce Thompson Inst. 7 : 231-248. 1935.
9. Denny, F. E. Hastening the coloration of lemons. Jour. Ag. Res. 27 : 757-771. 1924.
10. Denny, F. E. Testing plant tissue for emanations causing leaf epinasty. Contributions from Boyce Thompson Inst. 7 : 341-347. 1935.
11. Elmer, O. H. Growth inhibitions of potato sprouts by volatile products of apples. Science 75 : 191-193. 1932.
12. Elmer, O. H. Growth inhibitions in the potato caused by a gas emanating from apples. Jour. Ag. Res. 52 : 609-626. 1936.
13. Fidler, J. C. Studies of the physiologically-active volatile organic compounds produced by fruits. I. Jour. Hort. Sc. 24 : 178-188. 1948.
14. Fidler, J. C. Studies of the physiologically-active volatile organic compounds produced by fruits. II. Jour. Hort. Sc. 25 : 81-110. 1950.
15. Finch, A. H. The use of ethylene to improve pecan harvesting. Proc. Amer. Soc. Hort. Sc. 34 : 74-77. 1936.
16. Gane, R. Production of ethylene by some ripening fruit. Nature: 134, 1008. 1934.
17. Gane, R. Tainting and the volatile products of fruits. Great Brit., Dept. Sci. & Ind. Res. Rep. of the Food Invest. Bd. for 1933, pp. 122-128. 1934.
18. Gane, R. Identification of ethylene among the volatile products of ripe apples. Great Brit. Dept. of Sci. & Ind. Res. Rep. of the Food Invest. Bd. for 1934, pp. 122-123. 1935.
19. Gane, R. Formation of ethylene by plant tissues and its significance in the ripening of fruits. Jour. Pom. & Hort. Sci. 13 : 351-358. 1935.
20. Gane, R. Combustible gaseous products of fruits. Great Brit. Dept. Sci. & Ind. Res. Rep. of the Food Invest. Bd. for 1934, pp. 124-218. 1935.
21. Gane, R. Effects of ozone on bananas. Great Brit. Dept. Sci. & Ind. Res. Rep. of the Food Invest. Bd. for 1934, pp. 128-130. 1935.
22. Gane R. The production of a physiologically active vapour by unripe pears. Great Brit. Dept. Sci. & Ind. Res. Rep. of the Food Invest. Bd. for 1938, pp. 142-143. 1939.
23. Gerhardt, F., and B. D. Ezell. A method of estimating the volatile products liberated from stored fruit. Jour. Ag. Res. 58 : 493-503. 1939.
24. Gerhardt, F. Simultaneous measurement of $CO_2$ and organic volatiles in the internal atmosphere of fruits and vegetables. Jour. Ag. Res. 64 : 207-219. 1942.
25. Gerhardt, F. Air purification in apple and pear storages. Refrig. Eng. 58 : 145. 1950.
26. Gross, C. R., and R. M. Smock. Odour elimination in apple storage. Refrig. Eng. 50 : 535. 1946.
27. Hansen, E., and H. Hartman. The occurrence in pears of metabolic gases other than carbon dioxide. Oregon Agric. Exp. Sta. Bull. 342. 1935.
28. Hansen, E., and H. Hartman. The effect of ethylene and certain metabolic gases upon respiration and ripening of pears before and after cold storage. Plant Physiol. 12 : 441-454. 1937.
29. Hansen, E. Chemical changes of fruits ripened in the presence of ethylene. Science 86 : 2229. 1937.
30. Hansen, E., and B. E. Christensen. Chemical determination of ethylene in the emanations from apples and pears. Bot. Gaz. 101 : 403-309. 1939.
31. Hansen, E. Effects of ethylene on certain chemical changes associated with ripening of pears. Pl. Physiol. 14 : 145-162. 1939.
32. Hansen, E. Quantitative study of ethylene production in relation to respiration of pears. Bot. Gaz. 103 : 3. 1942.
33. Hansen, E. Relationship of ethylene production to respiration and ripening of premature pears. Amer. Soc. Hort. Sc. Proc. 43 : 69-72. 1943.
34. Hansen, E. Quantitative study of ethylene production in apple varieties. Plant Physiol. 20 : 631-635. 1945.
35. Hansen, E. Correspondence.
36. Harvey, R. M. The castor bean plant and laboratory air. Bot. Gaz. 56 : 439-442. 1913.
37. Harvey, R. B. Artificial ripening of fruits and vegetables. Minnesota Agric. Exp. Sta. Bull. 274. 1928.
38. Hibbard, R. P. The physiological effect of ethylene gas upon celery, tomatoes and certain fruits. Mich. Agric. Exp. Sta. Tech. Bull. 104. 1930.

**REFERENCES**—Continued


39. Huelin, F. E. Great Brit. Dept. Sci. & Ind. Res. Rep. of the Food Invest. Bd. for 1932. 1933.
40. Hulme, A. C. Metabolism of nitrogen in apple fruits. Great Brit. Dept. Sci. & Ind. Res. Rep. Food Invest. Bd. for 1937. 1938.
41. Isaac, W. E. Investigations on the active substance produced by peaches and plums. S. Africa Dept. of Agric. Low Temp. Res. Sta. Bull. for 1937-1938, pp. 93-112. 1939.
42. Kidd, F., and C. West. The course of respiratory activity throughout the life of an apple. Great Brit. Dept. Sci. & Ind. Res. Rept. Food Invest. Bd. for 1924, pp. 27-33. 1925.
43. Kidd, F., and C. West. Forecasting the life of an apple. Great Brit. Dept. Sci. & Ind. Res. Rep. Food Invest. Bd. for 1927, pp. 23-27. 1928.
44. Kidd, F., and C. West. Changes in the respiratory activity of apples during senescence at different temperatures. London, Proc. Roy. Soc. Series B. 106. 1930.
45. Kidd, F., and C. West. Effects of ethylene and apple vapours on the ripening of fruit. Great Brit. Dept. Sci. & Ind. Res. Rep. of Food Invest. Bd. for 1932, pp. 55-58. 1933.
46. Kidd, F., and C. West. The influence of the composition of the atmosphere upon the incidence of the climacteric. Great Brit. Dept. Sci. & Ind. Res. Rept. Food Invest. Bd. for 1933. 1934.
47. Kidd, F. The respiration of fruits. Great Brit. Royal Inst. Weekly Evening Meeting. Nov. 19, 1934.
48. Kidd, F., and C. West. The effect of ethylene on apples at low temperatures, evidence for the production of ethylene by unripe immature fruit. Great Brit. Dept. Sci. & Ind. Res. Rep. Food Invest. Bd. for 1934, pp. 119-122. 1935.
49. Kidd, F., and C. West. Cold storage of English-grown Conference and Doyenne de Comice pears, the relation between storage temperature and mean duration of life. Great Brit. Dept. Sci. & Ind. Res. Rep. Food Invest. Bd. for 1935, pp. 85-96. 1936.
50. Kidd, F., and C. West. Cold storage and gas storage of English-grown William's Bon Chretien pears. Great Brit. Dept. Sci. & Ind. Res. Rep. Food Invest. Bd. for 1936, pp. 113-126. 1937.
51. Kidd, F., and C. West. The effect of ethylene on the respiratory activity and the climacteric of apples. Great Brit. Dept. Sci. & Ind. Res. Rep. Food Invest. Bd. for 1937, pp. 108-114. 1938.
52. Kidd, F., and C. West. Individual variation in apples. Great Brit. Dept. Sci. & Ind. Res. Rep. Food Invest. Bd. for 1937, pp. 114-115. 1938.
53. Kidd, F., and C. West. Production of volatiles by apples: Effects of temperature, maturity, technique of estimation, etc. Great Brit. Dept. Sci. & Ind. Res. Rep. Food Invest. Bd. for 1938, pp. 136-139. 1939.
54. Kidd, F., and C. West. The rate of respiration and production of volatiles of Conference pears: Effects of treatment with ethylene, temperature, wounding. Great Brit. Dept. Sci. & Ind. Res. Rep. Food Invest. Bd. for 1938, pp. 139-142. 1939.
55. Kidd, F., C. West, and A. C. Hulme. Rise in insoluble ("protein") fraction of the total nitrogen during the climacteric in apples and pears, and the effects on this phenomenon of retarding the climacteric by carbon dioxide or simulating the climacteric by ethylene. Great Brit. Dept. Sci. & Ind. Res. Rep. Food Invest. Bd. for 1938, p. 119. 1939.
56. Kidd, F., and C. West. The climacteric in early and late varieties of apple on the tree. Great Brit. Dept. Sci. & Ind. Res. Rep. of Food Invest. Bd. for 1939, pp. 57-59. 1949.
57. MacRill. Calif. Fruit Growers' Exchange, Field Service Dept. Correspondence.
58. Miller, E. V., J. R. Winston, and D. F. Fisher. Production of epinasty by emanations from normal and decaying citrus fruits and from Penicillium digitatum. Jour. Ag. Res. 60 : 269-278. 1940.
59. Nelson, R. C. The quantity of ethylene present in apples. Plant Physiol. 12 : 1004-1005. 1937.
60. Nelson, R. C. Quantitative study of the production of ethylene by ripening McIntosh. Plant Physiol. 15 : 149-151. 1940.
61. Nelson, R. C. Studies on the production of ethylene in the ripening process in apples and bananas. Food Res. 4 : 2. 1939.
62. Niederl, J. B., and M. E. Brenner. A micro-method for identification and estimation of ethylene in ripening fruits. Mikrochemie 24 : 134-135. 1938.
63. Niederl, J. B., N. W. Brenner, and —. —. Kelley. The identification and estimation of ethylene in the volatile products of ripening bananas. Amer. Jour. Bot. 25 : 357-361. 1938.
64. Phillips, W. R. Air filters for storage rooms. Div. Hort., Central Exp. Farm, Ottawa. Rep. on Low Temp. Invest., 1943-1945, p. 31. *(unpublished).*

**REFERENCES**—Concluded

65. Phillips, W. R. Oil dipping as a means of superficial scald control. Div. Hort., Central Exp. Farm, Ottawa. Rep. on Low Temp. Invest., 1947-1948, pp. 17-20.
66. Phillips, W. R. Gas storage. Div. Hort., Central Exp. Farm, Ottawa. Rep. on Low Temp. Invest., 1948-1949, pp. 1-3.
67. Potter, Nina A., and Dorothy Griffiths. The effect of temperature and gas mixtures on the production of volatile substances by apples during storage. Jour. Pom. & Hort. Sci. 23 : 171-177. 1947.
68. Power, F. B., and V. K. Chesnut. The odorous constituents of apples. Emanations of acetaldehyde from ripe fruit. Jour. Amer. Chem. Soc. 42 : 1509-1526. 1920.
69. Pratt, H. K., R. E. Young, and J. B. Biale. The identification of ethylene as a volatile product of ripening avocados. Plant Physiol. 23 : 526-531. 1948.
70. Sievers, A. F., and R. H. True. A preliminary study of the forced curing of lemons as practiced in California. U.S.D.A. Bureau of Plant Ind. Bull. 232. 1912.
71. Smith, A. J. M., and R. Gane. Influence of a gaseous product from apples on the germination of seeds. Great Brit. Dept. Sci. & Ind. Res. Rep. Food Invest. Bd. for 1932, pp. 156-158. 1933.
72. Smock, R. M. The influence of controlled atmosphere storage on respiration of McIntosh apples. Bot. Gaz. 104 : 1. 1942.
73. Smock, R. M. The influence of one lot of fruit on another. Amer. Soc. Hort. Sc. Proc. 40 : 187-192. 1942.
74. Smock, R. M. The influence of stored apples on the ripening of other apples stored with them. Cornell University Agric. Exp. Sta. Bull. 799. 1943.
75. Smock, R. M. The elimination from the atmosphere of ethylene evolved by apples. Amer. Soc. Hort. Sc. Proc. 44. 1944.
76. Smock, R. M., and F. W. Southwick. Studies on storage scald of apples. Cornell University Agric. Exp. Sta. Bull. 813. 1945.
77. Smock, R. M., and F. W. Southwick. Air purification in the apple storage. Cornell University Agric. Exp. Sta. Bull. 843. 1948.
78. Smock, R. M. Odour removal studies in refrigerated storage. Refrig. Eng. 55 : 257. 1948.
79. Southwick, F. W. The removal of organic emanations from the atmosphere surrounding stored apples. Jour. Ag. Res. 71 : 297-315. 1945.
80. Southwick, F. W. Some factors to consider in cold storage management. Massachusetts University Ext. Dept. Fruit Notes, 2-3. Dec. 30, 1949.
81. Thornton, N. C. Facts about "artificially" ripened fruit. Boyce Thompson Inst. Prof. Paper 1 : 31. Aug., 1940.
82. Uota, M., and R. M. Smock. Odour elimination in apple storage. Refrig. Eng. 50 : 535. 1946.
83. Van Doren, A. An air purification trial in a Wenatchee apple storage. Amer. Soc. Hort. Sc. Proc. 52 : 205-212. 1948.
84. Van Doren, A. Air purification in refrigerated storage rooms. Ice and Refrig. 116 : 61. 1949.
85. Walls, L. P. The nature of the volatile products from apples. Jour. of Pom. & Hort. Sc. 20 : 59-68. 1942.
86. Williams, C. Y. Harvesting and packing lemons. Queensland Agric. Jour. 63 : 270-279. 1946.

# DIGESTIBILITY STUDIES WITH RUMINANTS

## XV. THE EFFECT OF THE PLANE OF NUTRITION ON THE DIGESTIBILITY OF OATS IN AN OATS-HAY RATION[1]

C. J. Watson[2], W. M. Davidson[3], J. W. Kennedy[3] and P. E. Sylvestre[4]

*Division of Chemistry, Science Service, Ottawa, Canada*

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One phase in this series of digestibility studies with ruminants deals with the effect of high levels of feeding on the digestibility of cattle rations. Attention is being given to barley, oats and linseed oil meal. Previous work (3, 4, 5, 6), dealt with barley and linseed oil meal. The effect of the level of feeding on the digestibility of oats is necessary to complete the picture. The results of such a study are given in the present paper.

### PROCEDURE

Six grade Shorthorn steers, $1\frac{1}{2}$ to 2 years old, with an average weight of 427 kg. throughout the experiment, were used. They were numbered 7 to 12, respectively. Six rations were fed. One consisted of 6 kg. of hay; the other five of a mixture of 3 kg. of hay with, respectively, 1, 2, 3, 4 kg., and the maximum quantity of oats which the animals could consume. The average of this maximum for the six animals was 4.6 kg. The six rations were fed to the six animals through six periods. The experiment was set up in the form of a $6 \times 6$ randomized Latin square. Each period consisted of 28 days of which 4 were change-over, 12 preliminary and 12 collection. The hay was from the 1948 crop baled in the field. It was of good quality and consisted of 80 per cent clover and 20 per cent grass. The oats were Western Canada Feed No. 1. The experiment commenced in November 1948 and was completed in April 1949.

### PROGRESS OF EXPERIMENT

In the second period, animal 8, receiving the maximum feed, refused some feed at the beginning of the collection period. On the fourth day one complete ration was withheld. For the remaining 8 days the animal consumed all its daily rations. The results in this case were considered satisfactory. All the remaining digestion trials were completed without incident.

### RESULTS

The calculations of the individual coefficients are not shown since they were too extensive. A summary of the results is given in Tables 1 and 2 with an analysis of variance in Table 3. For the dry matter, organic matter, ether extract, crude fibre, energy and T.D.N., there were no statistically significant differences between the mean coefficients of digestibility for either the periods or the animals. In the case of the nitrogen the differences between the means for periods were significant.

[1] Contribution No. 181 of the Division of Chemistry, Science Service, Canada Department of Agriculture, Ottawa, Canada, in co-operation with the Division of Animal Husbandry, Experimental Farms Service, Canada Department of Agriculture.

[2] Head, Animal Nutrition, Science Service (deceased).

[3] Technician, Science Service.

[4] Assistant Animal Husbandman, Experimental Farms Service.

TABLE 1.—SUMMARY OF COEFFICIENTS OF DIGESTIBILITY OF TOTAL RATIONS ARRANGED IN A 6 × 6 LATIN SQUARE. (COEFFICIENTS IN PER CENT, ANIMAL NUMBERS IN BRACKETS INCLUDED FOR FIRST SQUARE ONLY)

| Nutrient | Period | Coefficients of following rations* | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | | Hay | Hay 3 Oats 1 | Hay 3 Oats 2 | Hay 3 Oats 3 | Hay 3 Oats 4 | Hay 3 Oats max.† | |
| Dry matter | 1 | 54 ( 7) | 61 (12) | 64 ( 9) | 63 ( 8) | 63 (11) | 58 (10) | 60.6 |
| | 2 | 54 ( 9) | 60 (10) | 61 (11) | 62 (12) | 68 ( 7) | 65 ( 8) | 61.5 |
| | 3 | 54 (12) | 57 (11) | 60 (10) | 61 ( 7) | 61 ( 8) | 63 ( 9) | 59.4 |
| | 4 | 55 ( 8) | 59 ( 7) | 62 (12) | 63 (10) | 65 ( 9) | 61 (11) | 60.9 |
| | 5 | 55 (10) | 61 ( 9) | 61 ( 8) | 62 (11) | 62 (12) | 64 ( 7) | 60.8 |
| | 6 | 53 (11) | 53 ( 8) | 59 ( 7) | 63 ( 9) | 61 (10) | 62 (12) | 58.6 |
| | Means | 54.1 | 58.5 | 61.3 | 62.4 | 63.4 | 62.1 | |
| Organic matter | 1 | 55 | 63 | 66 | 65 | 65 | 60 | 62.2 |
| | 2 | 55 | 61 | 62 | 64 | 70 | 66 | 62.8 |
| | 3 | 55 | 58 | 62 | 62 | 62 | 64 | 60.6 |
| | 4 | 56 | 60 | 63 | 64 | 66 | 63 | 61.8 |
| | 5 | 57 | 62 | 63 | 64 | 64 | 65 | 62.4 |
| | 6 | 54 | 55 | 61 | 64 | 63 | 63 | 60.0 |
| | Means | 55.2 | 59.8 | 62.7 | 63.7 | 64.8 | 63.6 | |
| Nitrogen | 1 | 41 | 55 | 62 | 61 | 62 | 61 | 56.6 |
| | 2 | 50 | 58 | 63 | 66 | 71 | 69 | 62.6 |
| | 3 | 57 | 61 | 74 | 68 | 66 | 69 | 65.9 |
| | 4 | 48 | 59 | 57 | 62 | 66 | 62 | 58.9 |
| | 5 | 51 | 61 | 64 | 62 | 66 | 68 | 61.9 |
| | 6 | 52 | 57 | 62 | 68 | 65 | 67 | 62.1 |
| | Means | 49.8 | 58.4 | 63.5 | 64.4 | 65.9 | 66.0 | |
| Ether extract | 1 | 0 | 67 | 77 | 82 | 82 | 82 | 65.0 |
| | 2 | 15 | 63 | 73 | 79 | 86 | 86 | 67.1 |
| | 3 | 25 | 71 | 76 | 82 | 84 | 83 | 70.2 |
| | 4 | 42 | 74 | 77 | 87 | 89 | 81 | 75.0 |
| | 5 | 8 | 64 | 74 | 81 | 83 | 82 | 65.4 |
| | 6 | 15 | 63 | 77 | 81 | 74 | 76 | 64.4 |
| | Means | 17.7 | 66.9 | 75.5 | 82.1 | 83.2 | 81.6 | |
| Crude fibre | 1 | 48 | 52 | 51 | 43 | 44 | 34 | 45.5 |
| | 2 | 50 | 49 | 45 | 43 | 49 | 41 | 46.1 |
| | 3 | 49 | 42 | 46 | 41 | 39 | 42 | 43.1 |
| | 4 | 49 | 43 | 44 | 43 | 44 | 39 | 43.6 |
| | 5 | 48 | 51 | 46 | 43 | 38 | 39 | 44.3 |
| | 6 | 48 | 41 | 45 | 46 | 40 | 44 | 43.9 |
| | Means | 48.7 | 46.1 | 46.2 | 43.0 | 42.7 | 39.8 | |
| N-free extract | 1 | 64 | 70 | 73 | 73 | 72 | 68 | 69.8 |
| | 2 | 61 | 69 | 70 | 73 | 77 | 74 | 70.6 |
| | 3 | 61 | 67 | 69 | 71 | 70 | 71 | 68.2 |
| | 4 | 64 | 71 | 73 | 73 | 73 | 71 | 70.8 |
| | 5 | 65 | 70 | 71 | 72 | 72 | 74 | 70.7 |
| | 6 | 60 | 63 | 68 | 71 | 71 | 70 | 67.1 |
| | Means | 62.4 | 68.4 | 70.7 | 72.0 | 72.5 | 71.2 | |

* The coefficients were calculated to one decimal place but are shown here in unit numbers.
† Mean maximum consumption for six periods for oats was 4.6 kg.

TABLE 1.—SUMMARY OF COEFFICIENTS OF DIGESTIBILITY OF TOTAL RATIONS ARRANGED IN A 6 × 6 LATIN SQUARE. (COEFFICIENTS IN PER CENT, ANIMAL NUMBERS IN BRACKETS INCLUDED FOR FIRST SQUARE ONLY)—*Concluded*

| Nutrient | Period | Coefficients of following rations* | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | | Hay | Hay 3 Oats 1 | Hay 3 Oats 2 | Hay 3 Oats 3 | Hay 3 Oats 4 | Hay 3 Oats max.† | |
| T.D.N. in dry matter | 1 | 52 | 61 | 65 | 64 | 65 | 60 | 61.0 |
| | 2 | 52 | 59 | 61 | 64 | 69 | 66 | 61.8 |
| | 3 | 52 | 56 | 62 | 63 | 63 | 65 | 60.0 |
| | 4 | 53 | 59 | 62 | 64 | 66 | 63 | 61.1 |
| | 5 | 53 | 61 | 62 | 63 | 64 | 66 | 61.6 |
| | 6 | 51 | 54 | 60 | 64 | 63 | 64 | 59.4 |
| | Means | 52.1 | 58.2 | 62.0 | 63.6 | 65.0 | 64.0 | |
| Energy | 1 | 52 | 59 | 62 | 64 | 61 | 57 | 59.0 |
| | 2 | 50 | 59 | 61 | 62 | 68 | 64 | 60.5 |
| | 3 | 51 | 56 | 69 | 60 | 60 | 62 | 58.1 |
| | 4 | 52 | 58 | 60 | 62 | 64 | 60 | 59.4 |
| | 5 | 55 | 61 | 60 | 61 | 61 | 64 | 60.3 |
| | 6 | 52 | 54 | 60 | 65 | 62 | 64 | 59.4 |
| | Means | 51.9 | 57.7 | 60.4 | 62.3 | 62.7 | 61.7 | |

TABLE 2.—MEAN COEFFICIENTS OF DIGESTIBILITY OF NUTRIENTS IN TOTAL RATIONS ARRANGED BY ANIMALS. (MEANS OF SIX VALUES)

| Animal No. | Mean coefficients in per cent of following nutrients | | | | | | | Mean T.D.N. in dry matter per cent |
|---|---|---|---|---|---|---|---|---|
| | Dry matter | Organic matter | Nitrogen | Ether extract | Crude fibre | N-free extract | Energy | |
| 7 | 60.9 | 62.2 | 61.4 | 66.9 | 44.2 | 70.7 | 60.3 | 61.5 |
| 8 | 59.8 | 61.1 | 60.8 | 71.9 | 43.3 | 69.1 | 59.0 | 60.3 |
| 9 | 61.5 | 62.8 | 62.7 | 68.2 | 47.2 | 69.9 | 60.7 | 62.1 |
| 10 | 59.7 | 60.9 | 61.6 | 65.1 | 43.3 | 69.0 | 58.8 | 60.1 |
| 11 | 59.4 | 60.8 | 60.3 | 67.2 | 43.4 | 68.9 | 58.3 | 59.9 |
| 12 | 60.5 | 61.9 | 61.2 | 67.8 | 45.0 | 69.7 | 59.6 | 61.0 |

Periods 1 and 4 gave low results. Periods 2, 5 and 6 were intermediate and similar. Period 3 gave the highest results. There were similar differences between the means for N.F.E. The differences were not great, the range from lowest to the highest being 3.7 absolute per cent.

To determine if there were any effect of the plane of nutrition on the digestibility of the oats the following procedure was followed. The coefficients of digestibility of oats were calculated from the rations containing the maximum quantity. Using the means of these and the means of the hay ration as base values, the theoretical values for the other four rations were calculated. The differences between the means of the theoretical values and those of the corresponding observed ones were examined statistically by means of Fisher's method for unique samples (1). Standard errors of single means of the six observed values for each nutrient in the total ration were estimated from the error variance in Table 3. These are given in Table 4. The differences between the mean observed values and

TABLE 3.—ANALYSIS OF VARIANCE OF DATA IN TABLES 1 AND 2

| Nutrient | Variance due to | Sums of squares** | D/F | Variance** | F* |
|---|---|---|---|---|---|
| Dry matter | Ration | 357.46 | 5 | 71.49 | † |
| | Period | 36.91 | 5 | 7.38 | 1.90 |
| | Animal | 18.83 | 5 | 3.77 | ‡ |
| | Error | 77.56 | 20 | 3.88 | |
| Organic matter | Ration | 385.56 | 5 | 77.11 | † |
| | Period | 35.62 | 5 | 7.12 | 1.97 |
| | Animal | 19.76 | 5 | 3.95 | 1.09 |
| | Error | 72.27 | 20 | 3.62 | |
| Nitrogen | Ration | 1189.14 | 5 | 237.83 | † |
| | Period | 308.17 | 5 | 61.63 | 7.22 |
| | Animal | 19.81 | 5 | 3.96 | ‡ |
| | Error | 170.85 | 20 | 8.54 | |
| Ether extract | Ration | 19,210.70 | 5 | 3842.14 | † |
| | Period | 504.87 | 5 | 100.97 | 2.70 |
| | Animal | 149.96 | 5 | 29.99 | ‡ |
| | Error | 748.46 | 20 | 37.42 | |
| Crude fibre | Ration | 306.44 | 5 | 61.29 | 6.11 |
| | Period | 38.98 | 5 | 7.80 | ‡ |
| | Animal | 71.46 | 5 | 14.29 | 1.42 |
| | Error | 200.67 | 20 | 10.03 | |
| N-free extract | Ration | 422.64 | 5 | 84.53 | † |
| | Period | 72.87 | 5 | 14.57 | 4.56 |
| | Animal | 15.65 | 5 | 3.13 | ‡ |
| | Error | 63.93 | 20 | 3.20 | |
| T.D.N. in dry matter | Ration | 718.57 | 5 | 143.71 | † |
| | Period | 26.78 | 5 | 5.36 | 1.61 |
| | Animal | 22.37 | 5 | 4.47 | 1.35 |
| | Error | 66.49 | 20 | 3.32 | |
| Energy | Ration | 510.85 | 5 | 102.17 | † |
| | Period | 22.40 | 5 | 4.48 | ‡ |
| | Animal | 25.44 | 5 | 5.09 | 1.07 |
| | Error | 94.70 | 20 | 4.74 | |

* Necessary F for $N_1 = 5$, $N_2 = 20$ at P of 0.05 = 2.71.
Necessary F for $N_1 = 5$, $N_2 = 20$ at P of 0.01 = 4.10.
** Calculated to four decimal places, shown here to two.
† Obviously significant.
‡ Variance less than error variance.

TABLE 4.—STANDARD ERROR OF SINGLE MEANS OF SIX VALUES OF COEFFICIENTS OF DIGESTIBILITY

| Nutrient | Standard error |
|---|---|
| Dry matter | 0.80 |
| Organic matter | 0.78 |
| Nitrogen | 1.19 |
| Ether extract | 2.50 |
| Crude fibre | 1.29 |
| Nitrogen-free extract | 0.73 |
| T.D.N. in dry matter | 0.74 |
| Energy | 0.89 |

TABLE 5.—COMPARISON OF MEAN OBSERVED COEFFICIENTS OF DIGESTIBILITY OF NUTRIENTS IN TOTAL RATIONS WITH THE THEORETICAL MEANS

| Nutrient | Ration | | Coefficients | | Differences | "t" value* |
|---|---|---|---|---|---|---|
| | Hay, kg. | Oats, kg. | Observed | Theoretical | | |
| | | | % | % | | |
| Dry matter | 3 | 1 | 58.5 | 57.4 | + 1.1 | 1.37 |
| | 3 | 2 | 61.3 | 59.4 | + 1.9 | 2.36 |
| | 3 | 3 | 62.4 | 60.7 | + 1.7 | 2.11 |
| | 3 | 4 | 63.4 | 61.6 | + 1.8 | 2.24 |
| Organic matter | 3 | 1 | 59.8 | 58.7 | + 1.1 | 1.42 |
| | 3 | 2 | 62.7 | 60.7 | + 2.0 | 2.58 |
| | 3 | 3 | 63.7 | 62.1 | + 1.6 | 2.06 |
| | 3 | 4 | 64.8 | 63.1 | + 1.7 | 2.19 |
| Nitrogen | 3 | 1 | 58.4 | 57.3 | + 1.1 | 0.92 |
| | 3 | 2 | 63.5 | 61.2 | + 2.3 | 1.93 |
| | 3 | 3 | 64.4 | 63.6 | + 0.8 | 0.67 |
| | 3 | 4 | 65.9 | 65.2 | + 0.7 | 0.59 |
| Ether extract | 3 | 1 | 66.9 | 61.5 | + 5.4 | 2.16 |
| | 3 | 2 | 75.5 | 72.4 | + 3.1 | 1.24 |
| | 3 | 3 | 82.1 | 77.4 | + 4.7 | 1.88 |
| | 3 | 4 | 83.2 | 80.2 | + 3.0 | 1.20 |
| Crude fibre | 3 | 1 | 46.1 | 46.1 | 0 | — |
| | 3 | 2 | 46.2 | 43.9 | + 2.3 | 1.78 |
| | 3 | 3 | 43.0 | 42.0 | + 1.0 | 0.77 |
| | 3 | 4 | 42.7 | 40.5 | + 2.2 | 1.70 |
| N-free extract | 3 | 1 | 68.4 | 66.6 | + 1.8 | 2.47 |
| | 3 | 2 | 70.7 | 68.7 | + 2.0 | 2.74 |
| | 3 | 3 | 72.0 | 70.0 | + 2.0 | 2.74 |
| | 3 | 4 | 72.5 | 70.8 | + 1.7 | 2.33 |
| T.D.N. in dry matter | 3 | 1 | 58.2 | 57.0 | + 1.2 | 1.61 |
| | 3 | 2 | 62.0 | 59.9 | + 2.1 | 2.82 |
| | 3 | 3 | 63.6 | 61.8 | + 1.8 | 2.42 |
| | 3 | 4 | 65.0 | 63.3 | + 1.7 | 2.28 |
| Energy | 3 | 1 | 57.7 | 56.0 | + 1.7 | 1.91 |
| | 3 | 2 | 60.4 | 58.4 | + 2.0 | 2.25 |
| | 3 | 3 | 62.3 | 60.0 | + 2.3 | 2.59 |
| | 3 | 4 | 62.7 | 61.1 | + 1.6 | 1.80 |

* Necessary "t" at N of 20 at P of 0.05 = 2.09.
Necessary "t" at N of 20 at P of 0.01 = 2.84.

the theoretical ones were divided by the standard errors to give a set of "t" values. The means, their differences and the "t" values are given in Table 5.

It will be seen that the observed values were all somewhat higher than the theoretical ones based on the digestibility of oats when fed at the highest level. In the case of the dry matter, organic matter, nitrogen-free extract and total digestible nutrients in the dry matter of rations containing 2, 3 and 4 kilograms of oats, the differences were statistically significant. The differences were not statistically different for the ration containing the lowest level of oats. Differences in energy coefficients were significant in rations containing 2 and 3 kilograms of oats, but were not significant at

TABLE 6.—MEAN COEFFICIENTS OF DIGESTIBILITY OF THE NUTRIENTS IN OATS CALCULATED FROM THE TOTAL RATIONS WITH HAY

| Ration used | | | Coefficients of digestibility in per cent of the following nutrients | | | | | | T.D.N. in dry matter per cent |
|---|---|---|---|---|---|---|---|---|---|
| Hay, kg. | Oats, kg. | Dry matter | Organic matter | Nitrogen | Ether extract | Crude fibre | N-free extract | Energy | |
| 3 | 1 | 72 | 73 | 78 | 100 | 23 | 80 | 74 | 77 |
| 3 | 2 | 72 | 74 | 79 | 95 | 35 | 79 | 73 | 77 |
| 3 | 3 | 71 | 72 | 75 | 97 | 26 | 78 | 72 | 75 |
| 3 | 4 | 70 | 72 | 75 | 94 | 29 | 77 | 70 | 75 |
| 3 | Max.* | 67 | 69 | 74 | 91 | 22 | 75 | 68 | 72 |

* Mean of 4.6 kg.

the high and low level of oats. In the case where oats made up only one-fourth of the total ration, even though they had a higher digestibility than those in the ration with the maximum quantity, their effect on the total ration would be greatly diminished. The protein, ether extract and crude fibre digestibilities were not significantly affected by the level of feeding. With the ether extract the error was large. The rather large differences have no special significance.

The coefficients of digestibility of the oats were calculated by difference from the mixed rations. The mean values are given in Table 6. The progressive decrease in digestibility as the level of feeding was increased is evident. The nitrogen showed a decrease but, as stated above, the differences were within the experimental error. At maximum moderate levels of feeding the loss of T.D.N. was of the order of five absolute per cent.

This paper completes the studies on the effect of the plane of nutrition on the digestibility of barley, linseed oil meal and oats when fed to cattle with a basal ration of hay. Two previous papers on barley (4, 6) showed that when this feed was consumed in maximum quantities there was loss in total digestible nutrients of from 5 to 10 absolute per cent and in the digestibility of the protein of approximately five.

Two papers on linseed oil meal (3, 5) showed that at maximum levels of feeding there was a small but not significant decrease of from 2 to 3 absolute per cent in the total digestible nutrients and no change in the digestibility of the protein. The present paper on oats shows that at maximum levels of feeding there was a reduction of about 5 absolute per cent in the total digestible nutrients and a small but not significant change in the digestibility of the protein. The decrease in digestibility with oats was intermediate between that for the barley and that for the oil meal.

## SUMMARY AND CONCLUSIONS

1. Six grade Shorthorn steers were fed six rations consisting of hay and hay with increasing quantities of oats.

2. The digestibilities of these rations were determined.

3. As the quantity of oats in the ration was increased their digestibility decreased.

4. For the total digestible nutrients in the ration the decrease was of the order of 5 absolute per cent.

5. The decrease in the digestibilities of the protein was less and not statistically significant.

6. Considering the results of this and previous investigations, it has been shown that the influence of the plane of nutrition is most marked in the case of barley, less with oats and very slight with linseed oil meal.

7. The digestibility of the protein in these feeds was less affected than the carbohydrates by the plane of nutrition.

## ACKNOWLEDGMENTS

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## REFERENCES

1. Fisher, R. A. Statistical methods for research workers, p. 117. Oliver and Boyd, London. 1934.
2. Jones, D. B. Factors for converting percentages of nitrogen in feeds into percentages of protein. U.S. Dept. of Agr. Circular No. 183. 1931.
3. Watson, C. J., J. A. Campbell, W. M. Davidson, C. H. Robinson, and G. W. Muir. Digestibility studies with ruminants. VII. Plane of nutrition and digestibility of a hay-oil cake ration. Sci. Agr. 20 : 458-469. 1940.
4. Watson, C. J., W. M. Davidson, J. W. Kennedy, C. H. Robinson, and G. W. Muir. Digestibility studies with ruminants. XIV. The effect of the plane of nutrition on the digestibility of barley. Sci. Agr. 29 : 400-407. 1949.
5. Watson, C. J., J. W. Kennedy, W. M. Davidson, C. H. Robinson, and G. W. Muir. Digestibility studies with ruminants. XIII. The effect of the plane of nutrition on the digestibility of linseed oil meal. Sci. Agr. 29 : 263-272. 1949.
6. Watson, C. J., J. C. Woodward, W. M. Davidson, G. W. Muir, and C. H. Robinson. Digestibility studies with ruminants. II. Plane of nutrition and digestibility of a hay-barley ration. Sci. Agr. 17 : 11-21. 1936.

## APPENDIX

TABLE 7.—CHEMICAL COMPOSITION OF FEEDSTUFFS. (MEAN OF SIX VALUES)

| Feedstuff | Original dry matter | Composition of dry matter in per cent | | | | | Gross energy, Calories per 100 grams |
|---|---|---|---|---|---|---|---|
| | | Ash | Protein* | Ether extract | Crude fibre | N-free extract | |
| | % | % | % | % | % | % | |
| Hay | 86.68 | 5.65 | 9.89 | 0.99 | 39.14 | 44.33 | 449 |
| Oats | 86.93 | 3.57 | 12.33 | 4.38 | 13.00 | 66.73 | 467 |

* Protein factors: Hay – N × 6.25
Oats – N × 5.83 (Jones (2) ).

TABLE 8.—LIVE WEIGHTS OF ANIMALS

| Period No. | Live weights of following animals in kilograms | | | | | |
|---|---|---|---|---|---|---|
| | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | 429 | 405 | 408 | 432 | 413 | 398 |
| 2 | 428 | 439 | 422 | 405 | 403 | 406 |
| 3 | 438 | 436 | 432 | 408 | 394 | 431 |
| 4 | 437 | 441 | 445 | 431 | 411 | 413 |
| 5 | 462 | 422 | 425 | 458 | 422 | 435 |
| 6 | 454 | 412 | 451 | 458 | 431 | 450 |

# TRACTOR-MOUNTED FOUR-ROW PLOT SEEDER

A. I. Magee

*Division of Field Husbandry, Soils and Agricultural Engineering, Central Experimental Farm, Ottawa, Canada*

[Received for publication September 3, 1950]

A four-row power plot seeder was developed originally at the Dominion Experimental Station, Scott, Saskatchewan, in 1949, by A. B. Kusch *et al.* (1). Double-disc shallow furrow openers from a large grain drill were mounted on the drawbar of a four-wheel garden tractor, and Kemp "V" belt seeders attached to the tractor frame, about three feet above the ground, delivered the seed to the openers. As a result of this development, the Cereal Division of the Central Experimental Farm requested that a machine of this type be developed for use in Eastern Canada. There were two principal objections to the Scott unit. First, the front wheels of the tractor were close together which resulted in the packing of the soil in front of the seeders. To overcome this difficulty another type of tractor with a 36-inch tread is used. The second objection was that the disc type seeder was used. This has been replaced by the desired hoe-type opener.

## DESCRIPTION OF MACHINE

The seeding mechanism consists of four Kemp "V" belt type seeders mounted on a common shaft driven from the rear wheel of the tractor.

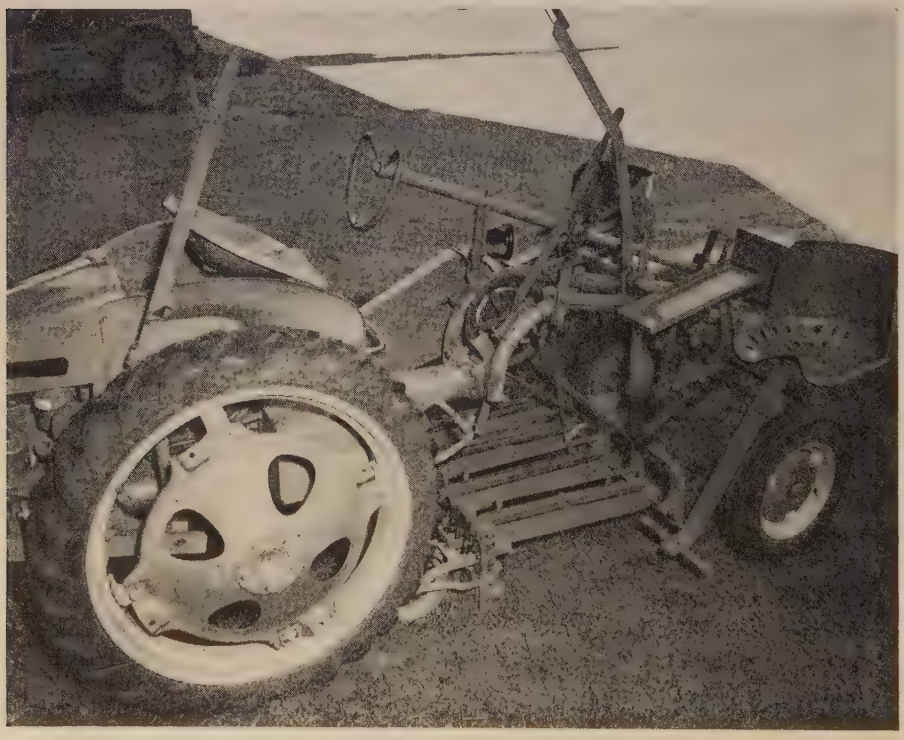

Figure 1. Side view showing chain and V-belt drive assembly to Kemp "V" belt seeders.

With this shaft attached to a bracket which is clamped to the lift-arms of the tractor, the seeding unit can be easily removed. The seeders are mounted close to the ground which reduces the length of the dropping tubes, eliminates the possibility of seed contamination and allows the furrow openers to be readily inspected. Packing wheels are used to ensure a uniform firmness of the seed-bed and uniform planting. The seeding units are lifted by means of a cable and lever. The tractor lift is used to adjust the tension of the drive belt and permits sufficient elevation for clearance when moving on the road.

## OPERATION AND RESULTS

For most efficient use of the machine, three men are necessary, one to operate the tractor and two to load the seeder belts. Bucket seats are mounted on the machine for the convenience of the seeding operators. It has been found that three men with this machine can seed more than five men using hand seeders. The plots seeded with the tractor-mounted unit showed some improvement over the hand seeded plots. Under average seed-bed conditions, the weight of the seeding unit is sufficient to force the hoe-type openers to the desired depth, thus eliminating the need for pressure springs.

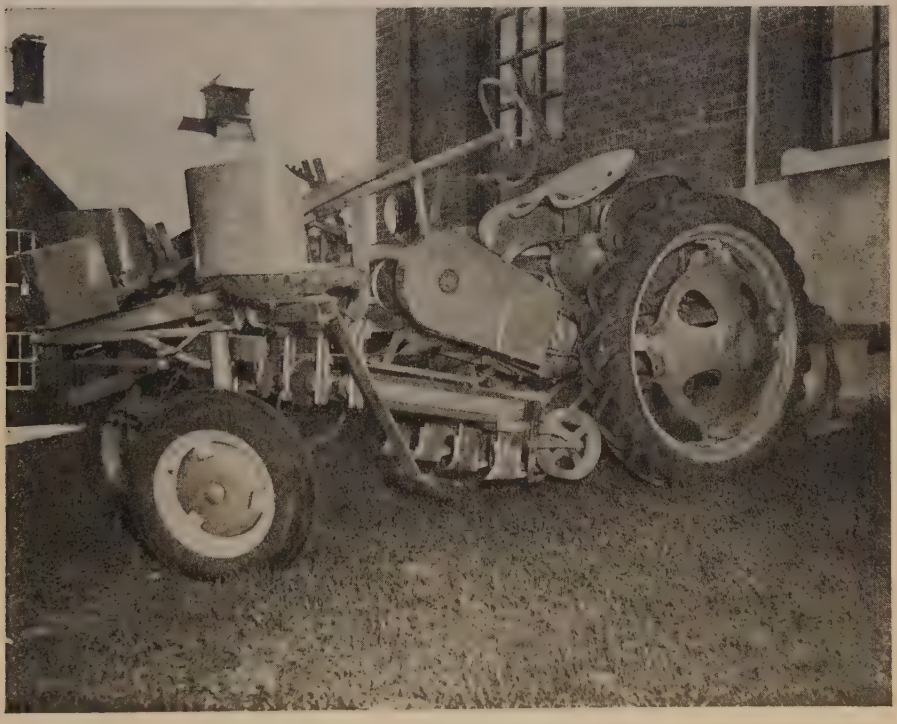

FIGURE 2. Side view, showing the seeding attachment raised, which provides ample road clearance.

## SUMMARY

A tractor-mounted four-row plot seeder, using Kemp "V" belt type seeding units, has been developed for plot work at the Central Experimental Farm, Ottawa.

## ACKNOWLEDGMENT

The author is greatly indebted to J. G. C. Fraser, Cereal Division, Central Experimental Farm, for suggestions regarding design, and to H. Gooding, Field Husbandry Division, for details of construction.

## REFERENCE

1. Kusch, A. G., *et al.* A four-row power plot seeder. Sci. Agr. 30 : 201-208. 1950.

# RHIZOMA ALFALFA: CHROMOSOME STUDIES OF THE PARENT STOCKS

R. A. Nilan[1]

[Received for publication August 10, 1950]

## INTRODUCTION

Rhizoma, a new alfalfa variety released in 1948 by the Department of Agronomy, the University of British Columbia, is characterized by a distinctive spreading habit of growth. It is tolerant to low temperatures and produces an abundant crop of forage and seed.

The variety originated following a cross between two species: *Medicago falcata* var. "Don", an importation from Russia by Hansen, the American plant explorer, and *Medicago sativa* var. Grimm and/or Ontario Variegated. The "Don" variety was the pistillate parent. It is a very small plant of prostrate habit, having yellow flowers and producing rhizomes which originate one to three inches below the soil surface. The staminate parent was an alfalfa of the well-known Grimm type which is characterized by a vigorous and upright habit of development. This variety has variegated flowers and does not produce rhizomes.

Rows of "Don" and variegated alfalfas were grown side by side to encourage natural crossing (3). Two hundred and fifty seeds collected from "Don" (i.e. *M. falcata*) plants were grown. Six of the resulting plants were obviously hybrids since they possessed the definite rhizomatous characteristic of the "Don" variety and a vigorous top growth similar to that of the Grimm variety.

Moe developed a breeding program based mainly on mass selection wherein these six hybrids, H-7, H-56, H-68, H-71, H-156, and H-190, were used as the parent stocks. The new variety, Rhizoma, is a result of selection through six generations. Certain anomalies have appeared in the variety. Many lines exhibit a high degree of self-tripping and in certain robust lines dwarfs, twins and weak plants appear frequently. Simple Mendelian segregations have not been observed throughout the course of this program.

The atypical features and the hybrid origin have led to questions regarding the nature and behaviour of the chromosomes of Rhizoma. Consequently, the cytology of the parent species, of the six original hybrids, and of some plants of the $F_2$ and subsequent generations has been studied.

## MATERIALS AND METHODS

Clones of the Grimm variety, of the original *M. falcata* var. "Don" parent, and of the six original hybrids were grown in the greenhouse. Plants of the $F_2$ and subsequent generations were grown in the field. Both buds and root tips were collected from the various plants, fixed in Carnoy's solution, and stored in alcohol until used. The chromosome counts were made from aceto-carmine smear preparations.

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[1] Graduate Assistant and holder of an Agricultural Institute of Canada Scholarship, Department of Agronomy, University of British Columbia; now Research Assistant, Department of Genetics, University of Wisconsin.

FIGURE 1. Grimm (*M. sativa*), meiosis, late second anaphase. (× 1775).

FIGURE 2. "Don" (*M. falcata*), somatic chromosomes, 2n = 16. (× 1775).

FIGURE 3. H-190, somatic chromosomes, 2n = 32. (× 1775).

FIGURE 4. H-156, somatic chromosomes, 2n = 32. (× 1775).

FIGURE 5. H-190, meiosis, second anaphase. (× 1775).

FIGURE 6. H-71, meiosis, first anaphase, 16 + 16. (× 1775).

FIGURE 7. H-7, meiosis, second anaphase, unequal rate of division, lagging of chromosomes. (× 1775).

FIGURE 8. H-68, somatic chromosomes, 2n = 24. (× 810).

FIGURE 9. H-56, meiosis, late second anaphase after an unequal distribution of univalents during the first division, lagging chromosomes. (× 1775).

FIGURE 10. H-56, meiosis, late first anaphase, lagging chromosomes and micronuclei. (× 1775).

FIGURE 11. H-68, meiosis, late anaphase, dividing bivalent at one pole. (× 1775).

## RESULTS

A fairly regular type of meiosis occurs during the course of microsporogenesis in the strain of *Medicago sativa* var. Grimm which was used as the staminate parent. The haploid chromosome number is usually 16 (Figure 1). The meiotic behaviour in this strain is typical of that which occurs in the commercial alfalfa with 32 somatic chromosomes.

The pistillate parent (*M. falcata* var. "Don") possesses 16 somatic chromosomes (Figure 2). Eight pairs of chromosomes showing slight individuality are present at meiosis.

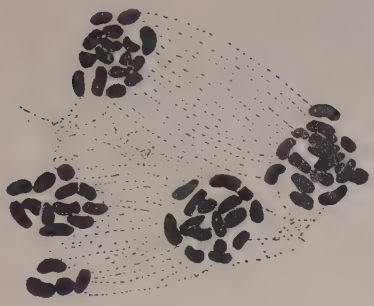
Hybrids H-7, H-71, H-156, and H-190 are tetraploids possessing 32 somatic chromosomes (Figures 3 and 4). Their meiosis is fairly regular (Figures 5 and 6) although lagging chromosomes are frequent (Figure 7).

Hybrids H-56 and H-68, on the other hand, are probably triploids possessing 24 somatic chromosomes (Figure 8) although better counts should be obtained. Irregular meiosis with the formation of spores containing unequal chromosome numbers is usual and lagging chromosomes and micronuclei are frequent (Figures 9, 10 and 11). The commonest haploid chromosome number is 12.

Selected plants of the $F_2$ and succeeding generations leading to the Rhizoma variety are tetraploids with 32 somatic chromosomes. Confirmation of this observation is obtained in counts made by J. M. Armstrong, Central Experimental Farm, Ottawa, and V. C. Brink, the University of British Columbia.

## DISCUSSION

Triploid offspring usually occur in the higher plants when a cross is made between diploid and tetraploid species. An exception occurs following the cross between *M. falcata* (n = 8) and a variety of the common alfalfa, *M. sativa* (n = 16) when the former is used as the pistillate parent. Four of the six hybrids under investigation proved to be tetraploids. A similar phenomenon was found by Ledingham (2) following similar crosses between



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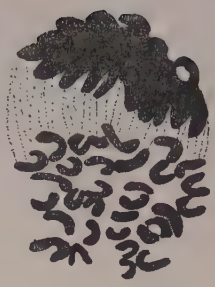

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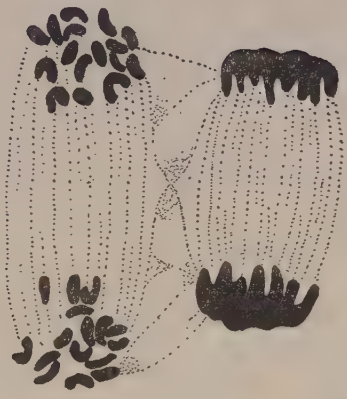

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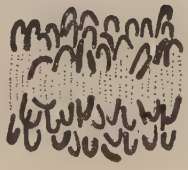

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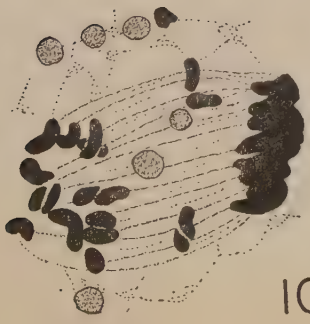

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the species except that all the progeny were tetraploids. The seventeen plants which he obtained were phenotypically alike and all proved to be partially fertile. Ledingham suggested that unreduced female gametophytes were occasionally produced by the *falcata* parent. Such gametophytes were fertilized with normal male gametes from the tetraploid *sativa* parent and gave rise to the tetraploid hybrids. This might well be the origin of the Rhizoma tetraploids under investigation.

The four tetraploids obtained during the course of these studies are unlike phenotypically since they differ in rhizome production, fertility and type of growth. The plant H-7 is, for instance, highly fertile and produces few rhizomes whereas H-71 has a very low seed set and there is abundant rhizomatous growth.

Two fertile triploids appeared along with the tetraploids following the cross under study. Ledingham (1940) did not obtain triploids from this cross but did obtain highly sterile triploids of unlike phenotype from the reciprocal cross.

The fact that the Rhizoma triploid hybrids are fertile and that one of the tetraploids is of low fertility has precedence in the reports of Nilsson and Andersson (4) and Julén (1). They have obtained hybrids between *M. falcata* and *M. sativa* which possessed the chromosome numbers of 32, 48, and 64 and have noted that there is little correlation between meiotic disturbance and pollen fertility.

## SUMMARY

Rhizoma, a new variety of alfalfa, has been developed from hybrids following a cross between a diploid alfalfa species (*M. falcata* var. "Don") and a tetraploid alfalfa (*M. sativa* var. Grimm and/or Ontario Variegated).

Four of the six original hybrids and the majority of plants in the succeeding generations leading to the variety are tetraploids possessing 32 chromosomes in the somatic tissues.

## ACKNOWLEDGMENT

The writer wishes to acknowledge with gratitude the assistance of V. C. Brink, Department of Agronomy, University of British Columbia, under whose direction this work was conducted.

## REFERENCES

1. Julén, G. Investigations on diploid, triploid and tetraploid lucerne. Hereditas 30 : 567-582. 1944.
2. Ledingham, G. F. Cytological and developmental studies of hybrids between *Medicago sativa* and a diploid form of *M. falcata*. Genetics 25 : 1-15. 1940.
3. Moe, G. G. Alfalfa studies: A preliminary study of the inheritance of certain morphological characters. Ph.D. thesis, Cornell University. 1928.
4. Nilsson, F., and E. Andersson. Polyploidy in the genus *Medicago*. Hereditas 29 : 197-198. 1943.

# ERADICATION OF POISON IVY (*RHUS RADICANS* L.)

## V. THE EFFECT OF FOLIAGE REMOVAL PRIOR TO TREATMENT ON THE CONTROL OF POISON IVY BY APPLICATIONS OF AMMONIUM SULFAMATE AND 2,4-DICHLOROPHENOXYACETIC ACID[1]

W. H. Minshall[2]

*Science Service, Ottawa, Canada*

[Received for publication September 6, 1950]

In Eastern Canada considerable poison ivy grows along roadsides and on railroad rights-of-way. As in the maintenance of such areas the plants are periodically cut, it was desired to learn whether or not this removal of the foliage would affect the killing of the ivy from herbicidal treatments. The experiment was designed to determine whether the removal of poison ivy foliage in June would affect the control obtained with July applications of ammonium sulfamate and 2,4-dichlorophenoxyacetic acid (2,4-D).

### MATERIALS AND METHODS

The experimental area consisted of a uniform stand of poison ivy with an average ground cover of 80 per cent. It was situated at Wrightville, Quebec, on very shallow soil over limestone bedrock. The surface of the ground was rough, with scattered stones present. In the original stand the upright stems of ivy were numerous, evenly distributed, and from 8 to 12 inches high. The area was of sufficient size to give 20 plots, each 100 square feet in area.

By means of a knapsack sprayer of 3-gallon capacity the ammonium sulfamate and 2,4-D were applied to the ivy foliage as aqueous sprays. One Imperial gallon of herbicide was applied to each plot. This amount was sufficient to cover each plot twice. Solution concentrations of 10.0 per cent ammonium sulfamate and of 0.1 per cent 2,4-D acid were calculated on the basis of weight. Ammonium sulfamate was dissolved directly in the water, but with 2,4-D acid the dry powder was first dissolved in melted carbowax 1500 and this solution was then added, with stirring, to lukewarm water. Carbowax was used in amounts sufficient to give a 0.5 per cent solution.

Estimates of poison ivy cover were made visually before and after each treatment. They represent the percentage of the area of the plot covered with poison ivy foliage. Since in previous work with ammonium sulfamate it was found that accurate estimates of poison ivy recovery were not possible until two years had elapsed from the time of the treatment, the final estimates in this experiment were taken in July of the second year after the herbicides were applied. For example, the estimation of ivy recovery in the plots sprayed in 1947 was made in July 1949.

To obtain a diversity of conditions at the time of treatment, the experiment extended over a three-year period. In each year stems and foliage were removed from a different group of 5 plots in June. Single treatments were made in each of the three years in July. The poison ivy plants were cut off at ground level with a long-handled sickle and the foliage was then removed from the plots by means of a fork. The cutting was done at about the time when the plants had completed their new

[1] Contribution No. 1044 from the Division of Botany and Plant Pathology, Science Service, Canada Department of Agriculture, Ottawa, Canada.

[2] Botanist.

growth for the year and were coming into flower. Plants were removed from the plots on the following dates: 1945—June 26; 1946—June 11; 1947—June 23. The times of herbicide applications were as follows: 1945—2.00 to 4.00 p.m., July 18; 1946—2.00 to 4.30 p.m., July 12; 1947—1.30 to 3.00 p.m., July 25. Sunny, clear weather prevailed during the application of all treatments. Three types of foliage were sprayed: (1) young plants in plots that had all the ivy removed in June of the current year, i.e., approximately one month previous to the treatment; (2) plants in plots that had all the ivy removed in June of the previous year; and (3) plants in plots that did not have the ivy removed. As in 1945 plots which had the ivy removed in the previous year were not available, no treatment was applied to this category. Plots in this category, however, were treated in 1946 and 1947 to give a total of two plots for each material. Plots in the other two categories—cut one month previous to spraying and not cut—received treatments in all three years.

The removal of foliage decreased the cover of poison ivy at the time of treatment. Ivy cover in the plots cut one month previous to spraying was from 50 to 55 per cent. In comparison to this recovery, the plants in the plots cut in the previous year had come back to within 5 or 10 per cent of the original cover of 80 per cent. At the time of treatment, the poison ivy leaves in all plots had a normal green colour.

The poison ivy plants in the three types of plots differed in size (Figure 1). In the uncut plots they were from 8 to 12 inches high, with normal-sized mature leaves. In the plots that had all the foliage removed one month previous to treatment, they were from 2 to 6 inches high, with young leaves about one-half the size of leaves on the uncut plots. In the plots that had all the foliage removed in June of the previous year, they were from 6 to 10 inches high, with the majority of the leaves just slightly smaller than the leaves in uncut plots, but they appeared to be somewhat later in reaching maturity than the plants in the uncut plots. Although the plants in the plots cut in the previous year differed little in size and stage of maturity from the plants in uncut plots, there was a marked difference in size and maturity of the plants in these two types of plots and the plants in the plots cut one month previous to treatment. The leaves were smaller and younger in the plots cut one month previous to treatment.

## RESULTS

Table 1 gives the average percentage reduction of poison ivy resulting from the applications of ammonium sulfamate and 2,4-D acid. Good control was obtained with all applications of ammonium sulfamate, regardless of whether or not the foliage had been removed. Although a slightly greater reduction was secured in the plots from which the foliage was removed, the difference in the amount of reduction was not great enough to be considered significant. With 2,4-D, a good control was obtained in the plots, the foliage of which was cut in the previous month, but poor control in plots cut in the previous year, and even poorer control in uncut plots. It was evident that the removal of poison ivy foliage, as carried out in this experiment, was beneficial in the control of ivy with July applications of 0.1 per cent 2,4-D acid, but had no significant effect on the control with July applications of 10.0 per cent ammonium sulfamate.

FIGURE 1. The effect of foliage removal on the poison ivy at the time of treatment in July. *Left to right:* The size of the plants in plots cut in June of the current year, in plots cut in June of the previous year, and in plots not cut.

TABLE 1.—THE EFFECT OF THE REMOVAL OF FOLIAGE ON THE CONTROL OF POISON IVY WITH JULY APPLICATIONS OF 10.0 PER CENT AMMONIUM SULFAMATE AND 0.1 PER CENT 2,4-D ACID

| Cutting treatment | Average percentage reduction of ground cover in July of the second year after application | |
|---|---|---|
| | Ammonium sulfamate | 2,4-D acid |
| | % | % |
| Cut in June of the year of application | 87 | 83 |
| Cut in June of the year previous to application | 91 | 40 |
| Not cut | 80 | 27 |

## DISCUSSION

Significant differences in the control of poison ivy were obtained with the 2,4-D applications. The age of the poison ivy leaves in the plots differed as a result of the cutting treatments. Was this difference in the age of the leaves responsible for the differences obtained in control? Grigsby (1), Minshall (2), and Stoddard (5) have reported that 2,4-D is more effective when applied to young or rapidly growing poison ivy plants than when it is applied to more mature plants. In an investigation of the effect of the age of bean plants on the absorption and the translocation of a growth regulating chemical, Mitchell (3) and Mitchell and Linder (4) found that partially expanded leaves, or leaves that had recently become fully expanded, absorbed and translocated the chemical more readily than did very young leaves or fully expanded mature leaves. This work of Mitchell and Linder suggests that under certain circumstances young bean leaves would be more severely affected by 2,4-D than would mature leaves. The field work cited above suggests that young poison ivy leaves would likewise be more severely affected by 2,4-D than would mature ivy leaves. In the present experiment the best control was obtained in the plots that had all the foliage removed one month previous to treatment and the poorest control was obtained in the plots that did not have the foliage removed. This difference in control suggests that the young recently expanded ivy leaves in the plots that had the foliage removed one month previous to spraying were more severely affected by the 2,4-D than were the mature plants in the plots that were not cut. It is possible, therefore, that the differences in control obtained from applications of 2,4-D were caused by the difference in age of the poison ivy leaves.

As the control of poison ivy did not differ significantly in the plots sprayed with ammonium sulfamate, it would appear that the age of the poison ivy plants had little if any effect on the absorption, translocation, or action of the sulfamate herbicide.

From other experiments conducted near Ottawa, Ontario, and reported previously (2), it was found that, although mid-June applications of 2,4-D acid gave a good control of poison ivy, applications made in July or later gave a very poor control. It would appear, therefore, that the

poor results obtained in the present experiment from the July applications of 2,4-D acid to uncut plots were normal for such applications, and that the good control from July applications of 2,4-D to plots cut the previous month were approximately the same as those obtained in other experiments by June applications to uncut plots. It is possible that if the poison ivy were cut at such a time as to permit application of the 2,4-D acid in mid-June, there might not be a great deal of difference in the control obtained with different cutting treatments. This suggestion is, of course, by way of conjecture, and it should be checked further, especially as somewhat variable results have been obtained occasionally with June applications of 2,4-D acid.

## SUMMARY

In an area with an 80 per cent stand of poison ivy all top growth was removed from certain plots in June. Other plots were not cut. In July applications of 10.0 per cent ammonium sulfamate and of 0.1 per cent 2,4-D acid, with carbowax as co-solvent, were made to normal uncut plots, to plots cut in June of the current year, and to plots cut in June of the previous year.

This removal of foliage had no significant effect on the control (80-90 per cent reduction) obtained with applications of sulfamate.

With 2,4-D the reduction in poison ivy was 27, 40, and 83 per cent for applications to uncut plots, to plots cut in the previous year, and to plots cut in the current year, respectively. The beneficial effect of foliage removal on subsequent 2,4-D acid treatments was probably due to an increased activity of the 2,4-D in the more recently expanded poison ivy leaves.

## REFERENCES

1. Grigsby, B. H. Some effects of 2,4-D on ragweed and certain woody plants. Mich. Agr. Expt. Sta. Quart. Bull. 28 : 304-310. 1946.
2. Minshall, W. H. Eradication of poison ivy (*Rhus radicans* L.) III. Further preliminary results with 2,4-dichlorophenoxyacetic acid formulations, ammonium sulfamate, and sodium chlorate. Sci. Agr. 28 : 140-141. 1948.
3. Mitchell, J. W. 2,4-D how it kills weeds. Agric. Chem. 3 : 28-30, 81. 1948.
4. Mitchell, J. W., and P. J. Linder. Absorption of radioactive 2,4-D I as affected by wetting agents. Proc. N. E. States Weed Cont. Conf. 1950 : 21-25. 1950.
5. Stoddard, E. M. Poison ivy and its eradication. Conn. Agr. Expt. Sta. Circ. 170 : 1-4. 1949.

# PROPAGATING HIGHBUSH BLUEBERRIES BY MOUNDING

E. L. Eaton[1]

*Dominion Experimental Station, Kentville, N.S.*

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The cultivated highbush blueberry is normally propagated by the rooting of hardwood or softwood cuttings. The medium is usually peat, sawdust or peat and sand. In New Jersey (2) the use of a lath house, enclosing the peat and sand beds, is a standard method. Elsewhere (1) (4) peat in a wire mesh tray in a tight, shaded cold frame is recommended. The latter method has been used at Kentville (3) and sawdust is sometimes substituted for peat with fair results.

It has long been recognized that some blueberry varieties root more easily than others. At Kentville, Katharine, Pioneer and Kengrape have been consistently more difficult to root than Rancocas or Burlington.

Where sawdust mulch was applied to the bearing blueberry plants at Kentville in 1940, many of the lower branches of some unnamed sorts developed roots in the sawdust layer. This observation led to a test of peat and sawdust for mounding.

## LOCATION

The plants used were set in 1937. The soil in this particular plantation varies widely within a short distance, and the part used has a sandy topsoil with a coarse gravel subsoil. The plants had made feeble growth under grass mulch until sawdust was applied in 1940. Clean cultivation in following years blended the sawdust with the top soil and stimulated more vigorous growth, which, however, was much behind that on the more fertile part of the plantation.

## MATERIALS AND METHODS

Four plants in each of two adjoining rows were selected, pruned back severely in the spring of 1945, and fertilized generously with 9-5-7 fertilizer. A frame of boards, 8 inches high, twelve feet long and three feet wide, was built around each set of plants. One frame was filled with softwood sawdust, the other with granulated peat. The sawdust frame surrounded three Pioneer and one Kengrape plant. The peat frame surrounded four Pioneer plants. The only watering was by natural rainfall. Both peat and sawdust settled somewhat the first season, and the frames were filled again in 1946.

## OBSERVATIONS

Leaf and twig growth came at the same time as that on the unenclosed plants. New twig growth occurred above, rather than below the mulch layer, and thus rooting was largely on two-year wood or older. Rooting was apparent on all plants by the late fall of 1945, but was considered too feeble for transplanting in the spring of 1946, when fertilizer was again applied within the rooting beds. When the frames were finally removed in the early spring of 1948, practically all the buried branches in both peat

[1] Senior Horticulturist (Native Fruits).

and sawdust revealed a vigorous and extensive, although one-sided, root system. In every case, the roots were chiefly on the lower side, so that the plants lacked the symmetrical, upright character of those grown from rooted cuttings in the usual nurseries. Study of the Pioneer plants ceased at this point; but the entire lot of Kengrape was set in a new plantation in 1949, where they have become firmly established as well-balanced, vigorous plants without a single miss at the end of three seasons. The row secured from this one parent plant numbers nine in all. The eight plants used for the test have again developed branches and tops equal in size to the untreated plants.

## DISCUSSION

It was expected that new shoots would appear below the sawdust, and that rooting would be on the new wood. Since this did not occur, it is believed that heading back a year in advance of mounding might stimulate new sprouts from around the crown, which in turn, might produce more symmetrical plants. It seemed at first as if this method might be too slow and costly for common use. However, none of the parent plants was large enough to yield many cuttings, and these younger and smaller plants were thus brought into reproduction more rapidly. Propagating frames demand close attention to ventilation, followed by transplanting to nursery-beds. In this instance, the mounds received no such care, and the plants set directly in their permanent places have been fully equal to the best 2-year-old plants of other varieties.

## SUMMARY

1. Kengrape and Pioneer highbush blueberries, normally difficult to root in solar frames, have rooted freely on the branches when mounded with softwood sawdust or granulated peat.

2. Plants secured by this method were irregular in shape when first transplanted, but have rapidly become normal in every way.

3. Plants too small to supply many ordinary cuttings were satisfactory for mounding.

4. The method had the advantage of needing very little attention after the frames were placed around the plants and filled with the rooting media.

## REFERENCES

1. Bailey, J. S., H. J. Franklin, and J. L. Kelly. Blueberry cultivation in Massachusetts. Bull. 358, Massachusetts. 1941.
2. Doehlert, C. A. Propagating blueberries from hardwood cuttings. Circular 490, New Jersey. 1945.
3. Eaton, E. L. The blueberry. Pub. 754, Farmer's Bull. 120, Ottawa. 1949.
4. Johnson, S. Essentials of blueberry culture. Circ. Bull. 188, Michigan. 1947.

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3. Copyright protection in the Americas under national legislation and inter-American treaties. 2d edition, revised. Manuel Canyes, Paul A. Colborn, and Luis Guillermo Piazza. Wash., Pan American union, 1950. 213 p.
4. The Fraser. Bruce Hutchison. New York, Rinehart & company, inc., 1950. 368 p. il. (Rivers of America books)
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6. Publications of the government of British Columbia, 1871-1947. Marjorie C. Holmes. Revision of publications of the government of British Columbia, 1871-1937, by Sydney Weston. Victoria, King's printer, 1950. 254 p.
7. Southern Rhodesia; a field for investment. (Salisbury) Public relations department, 1950. 59 p. il. tabs. map.
8. Manual of Arctic survival and useful Eskimo words. T. N. Freeman. Ottawa, 1950. 22 p. (processed) (Canada. Department of agriculture. Division of entomology. Miscellaneous publication series. ME–1)

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9. World outlook and state of food and agriculture, 1950. Wash., Food and agriculture organization of the United nations, 1950. 81 p. tabs. (processed) (In English and French)

## BIOLOGY

10. Mathematical biophysics. Revised edition. N. Rashevsky. Chicago, University of Chicago press, 1948. 669 p. figs. References at end of chapters.
11. Les richesses de la mer. Noël Boudarel. Paris, Paul Lechevalier, 1948. 549 p. figs. Ouvrages à consulter: pp. 547-548. (Encyclopédie biologique XXIX)

## BOTANY

12. Marin flora: Manual of the flowering plants and ferns of Marin county, California. John Thomas Howell. Berkeley, University of California press, 1949. 322 p. il.
13. Wild flowers of chalk and limestone. J. E. Lousley. London, Collins, 1950. 254 p. plates (col.) bibliography: pp. 229-235.
14. Researches on fungi. Volume VII. The sexual process in the Uredinales. A. H. Reginald Buller. Published for the Royal society of Canada. Toronto, University of Toronto press, 1950. 458 p. figs. Bibliographical footnotes.
15. The South African fungi and lichens to the end of 1945. Ethel M. Doidge. Pretoria, Government printer, 1950. 1094 p. plates. maps. (Bothalia, a record of contributions from the National herbarium, vol. 5, 1950)
16. Entwicklungs-und bewegungsphysiologie der pflanze. Erwin Bünning. Berlin, Springer-Verlag, 1948. 464 p. figs. References through the text. (Lehrbuch der pflanzenphysiologie)
17. El Aliso; a series of papers on the native plants of California. Anaheim, California, The Rancho Santa Ana botanic garden. Library has: Vol. 2, no. 3, Nov. 15, 1950.
18. Leguminous forage plants. D. H. Robinson. London, Edward Arnold, 1947. 119 p. figs. tabs. 2d edition.

## BOTANY—Continued

19. Arbres indigènes du Canada. Deuxième édition. Ottawa, 1950. 291 p. figs. plates. (Canada. Ministère des ressources et du développement économique. Service forestier. Bulletin 61)
20. Flora of the Cape Peninsula. Edited by R. S. Adamson and T. M. Salter. Cape Town, Juta & co., ltd., 1950. 889 p.
21. Maize in the great herbals. John J. Finan. Waltham, Mass., Chronica nica company, 1950. 191 p. il. bibliography: pp. 189-191.
22. The cacti of Arizona. Lyman Benson. Tucson, University of Arizona press, 1950. 134 p. figs. plates. 2d edition.
23. Nutrition de quelques myxomycètes en cultures pures et associées et leurs propriétés antibiotiques. J. C. Sobels. Gouda, N. V. Drukkerij v/h Koch & Knuttel, 1950. 135 p. figs. tabs. Index bibliographique: pp. 132-135.
24. Istituto botanico della universita laboratorio crittogamico, Pavia. Atti, serie 5. Latest number in library: Volume VI (3), 1950.

## BREWING

25. The art and science of brewing. C. A. Kloss. London, Stuart and Richards, 1949. 121 p. figs. plates. bibliography: p. 117.

## CHEMISTRY—CHEMIC TECHNOLOGY

26. Physical methods of organic chemistry. Volumes I and II. Edited by Arnold Weissberger. New York, Interscience, 1945 and 1946. 1367 p. References at end of contributions. (Technique of organic chemistry)
27. Titanium; its occurrence, chemistry, and technology. Jelks Barksdale. New York, The Ronald press company, 1949. 591 p. Literature cited: pp. 489-566.
28. Annual review of physical chemistry, Volume I, 1950. Stanford, California, Annual reviews, inc., 1950. 382 p. References at end of contributions.
29. International colloquium on macromolecules. Proceedings. Amsterdam, 1949. Amsterdam, D. B. Centen's uitgevers-maatschappij N. V., 1950. 410 p. figs. tabs.
30. Dextran—a selected bibliography. Allene Jeanes. Peoria, Northern regional research laboratory, 1950. 13 p. (processed) (U.S. Department of agriculture. Bureau of agricultural and industrial chemistry. AIC-288)
31. Methods and costs of producing alcohol from grain by the fungal amylase process on a commercial scale. Production and marketing administration and Bureau of agricultural and industrial chemistry. Wash., 1950. 38 p. figs. tabs. (U.S. Department of agriculture. Technical bulletin no. 1024)
32. Les nouveaux matériaux de synthèse américains. H. R. Simonds, M. H. Bigelow, et J. V. Sherman. Traduit . . . par G. Génin. Paris, Dunod, 1947. 410 p. figs. tabs. bibliographie: pp. 366-398.
33. The chemical analysis of foods. Henry Edward Cox. Fourth edition. London, Churchill, 1950. 340 p. figs. tabs.
34. Preservation of the color and shape of flowers. Randolph C. Specht. Gainesville, 1950. 29 p. figs. tabs. plate (col.) (Florida engineering and industrial experiment station. Bulletin series no. 40)
35. Amberlite monobed deionization. Phila., Rohm & Haas company, 1950. 12 p. figs. tabs.
36. Iodine and plant life; annotated bibliography 1813-1949. London, Chilean iodine educational bureau, 1950. 114 p.
37. Great Britain. Department of the government chemist, Annual report, 1949-50. London, H.M. stationery office, 1950. 35 p.

## CO-OPERATION

38. Saskatchewan co-operative producers limited. Twenty-sixth annual report, 1950. Regina, 1950. 48 p.
39. Saskatchewan co-operative extension services. Annual report, 1950. Regina, Department of co-operation and co-operative development, 1951. 24 p.
40. Co-operatives and labour. P. H. Casselman. (Reprinted from Culture, XI, pp. 280-302, 1950)

## DAIRY INDUSTRY—DAIRY RESEARCH

41. Byproducts from milk. Earle O. Whittier and Byron H. Webb. New York, Reinhold publishing corporation, 1950. 317 p. figs. tabs. References at end of chapters.
42. A survey of the literature on bactericidal effects of short electro-magnetic waves. H. Burton. Reading, 1949. 16 p. (National institute for research in dairying. Paper no. 1041)
43. Indian dairy department. Annual report, 1947. Calcutta, Government of India press, 1950. 29 p.
44. What about margarine? Chicago, National association of margarine manufacturers, 1950. 19 p.
45. The romance of cheese. Chicago, Kraft food company, 1950. 52 p. il.

## ECONOMICS—ECONOMIC SURVEYS—ECONOMIC POLICY

46. A reconstruction of economics. Kenneth E. Boulding. New York, Wiley, 1950. 311 p. figs. Bibliographical footnotes.
47. Canadian agricultural economics society. Proceedings, 1950. Ottawa, 1950. 156 p. (processed)
48. Readings in the theory of income distribution. Selected by a committee of The American economic association. Phila., The Blakiston company, 1946. 718 p. figs. Classified bibliography of articles: pp. 662-710. (Blakiston series of republished articles on economics. Vol. III)
49. Scottish agricultural economics; some studies of current economic conditions in Scottish farming. Volume I. Edinburgh, H.M. stationery office, 1950. 58 p. At head of title: Scotland. Department of agriculture.
50. Economic survey of inter-American agriculture. Volumes I and II. Washington, Pan American union, 1949. 228, 113 p. (processed)
51. Commonwealth economic committee. Annual report, April, 1949 to March, 1950. London, H.M. stationery office, 1950. 8 p.
52. Development and welfare in the West Indies 1947-49. Report by Sir Hubert Rance. (Barbados) 152 p.
53. The organisation for European economic co-operation. Paris, Organisation for European economic co-operation, 1950. 47 p. il. map.

## ENGINEERING—BUILDING CONSTRUCTION

54. Audels diesel engine manual. Audel staff. New York, Theo. Audel & co., 1948. 554 p. il.
55. Electricity in the home and on the farm. Forrest B. Wright. New York, John Wiley & sons, inc., 1950. 380 p. figs. tabs.
56. House construction details. Nelson L. Burbank. New York, Simmons-Boardman publishing corporation, 1942. 313 p. il. diagrs. plans.
57. Adequate farm wiring. J. A. McCurdy and E. F. Olver. State College, 1950. 24 p. figs. (Pennsylvania state college. Agricultural extension service. Circular 373)
58. Farm water supply. H. W. Kitching and T. R. C. Rokeby. Toronto, 1950. 45 p. figs. (Ontario department of agriculture. Statistics and publications branch. Bulletin 476)
59. Gasoline engine ignition. Department of agricultural engineering. Saskatoon, 1950. 28 p. il. (Saskatchewan. University. College of agriculture. Agricultural extension bulletin no. 19)
60. Construction and operation of ground equipment for applying concentrated sprays. S. F. Potts and others. New Haven, 1950. 35 p. figs. tabs. (Connecticut agricultural experiment station. Circular 178)
61. Poultry housing. Prepared by the staff of the Department of poultry husbandry, with plans by the Department of agricultural engineering . . . . Ontario agricultural college, Guelph, Ontario. Toronto, 1950. 12 p. il. plans. (Ontario department of agriculture. Statistics and publications branch. Extension circular 80)
62. Rational design criteria for sewage absorption fields. J. E. Kiker, jr. Gainesville, 1950. (Florida engineering and industrial experiment station. Technical paper series. No. 51) (Reprinted from Sewage and industrial wastes, vol. 22, no. 9, pp. 1147-1156, 1950)

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## FEEDING AND FEEDING STUFFS

68. National association of silo manufacturers. Proceedings of the thirty-eighth annual convention, Chicago, 1950. Norwich, N.Y., 1950. 142 p. (processed)
69. Making and feeding grass and legume silage in Nova Scotia. J. E. Shuh. Halifax, 1949. 15 p. figs. tabs. (Nova Scotia. Department of agriculture and marketing. Publication 1005)

## FERTILIZERS

70. Fertilizer experiments on Irish potatoes 1947-1948. T. O. Ellis. Kingston, 1950. 30 p. figs. tabs. (Jamaica. Department of agriculture. Bulletin no. 40, n.s.)
71. Results of experiments on yield, composition and responses to fertilizers of napier grass and guinea grass in Jamaica. T. O. Ellis and W. D. Burrowes. Kingston, 1950. 42 p. figs. tabs. (Jamaica. Department of agriculture. Bulletin no. 43, n.s.)
72. Fertilizer placement for arable crops. A. B. Stewart. Edinburgh, 1949. 12 p. (Scotland. Department of agriculture. Leaflet no. 3, n.s.)
73. Residual values of fertilizers and feeding stuffs. Second report (1950) of the Scottish standing committee. Edinburgh, 1950. 8 p. (Scotland. Department of agriculture. Advisory leaflet no. 17, n.s.)

## FOOD—FOOD PRESERVATION

74. Some aspects of food refrigeration and freezing. Study edited by Donald K. Tressler. Wash., 1950. 205 p. figs. tabs. (Food and agriculture organization of the United nations. FAO agricultural studies no. 12)
75. American society of bakery engineers, Twenty-sixth annual meeting, 1950. (Chicago) 1950. 396 p. il.
76. Canada. Department of agriculture. Fruit and vegetable products research committee. Annual report, 1949. Ottawa (1950) v.p. (processed)
77. Jam manufacture. George H. Rauch. London, Leonard Hill ltd., 1950. 201 p. il.
78. Canned foods; an introduction to their microbiology. J. G. Baumgartner. Third edition. London, Churchill, 1949. 278 p. figs. tabs.
79. State of Maine potato cook book. Augusta, Maine development commission, 1950. 63 p. col. illus.

## FORESTS AND FORESTRY

80. Forest products research. Report of the Forest products research board, with the report of the Director of forest products research, for the year 1948. London, H.M. stationery office, 1950. 46 p. il. At head of title: (Great Britain) Department of scientific and industrial research.
81. The changing forest situation; a study of conservation on state and private forest lands. Frank Sweeney. New York, American enterprise association, inc., 1950. 52 p. ("National economic problems" no. 435)

## GENETICS

82. Advances in genetics, volume III. Edited by M. Demerec. New York, Academic press inc., 1950. 267 p.
83. Population genetics and animal improvement. I. Michael Lerner. Cambridge, University press, 1950. 342 p. tabs. bibliography: pp. 317-333. (Cambridge biological studies)
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## HORTICULTURE

86. Apples and apple products. R. M. Smock and A. M. Neubert. New York, Interscience, 1950. 486 p. figs. tabs. references through the text. (Economic crops, volume II, edited by Z. I. Kertesz)
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89. Florida state horticultural society. Proceedings, Tampa, 1949. (Stuart, Florida) (1949) 247 p. figs. tabs.
90. Some good garden plants, containing descriptions of the plants which have received the Award of garden merit, 1922-1949. London, The Royal horticultural society, 1950. 91 p. figs.
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97. The Murphy and Wolcott blueberry varieties. E. B. Morrow and George M. Darrow. Raleigh, 1950. 7 p. il. (North Carolina agricultural experiment station. Special circular no. 10)
98. Breeding improved horticultural plants. II. Fruits, nuts, and ornamentals. A. F. Yeager. Durham, 1950. 16 p. il. (New Hampshire. University. Agricultural experiment station. Bulletin 383)
99. Breeding improved horticultural plants. I. Vegetables. A. F. Yeager. Durham, 1950. 23 p. il. (New Hampshire. University. Agricultural experiment station. Bulletin 380)
100. American orchid culture. Edward A. White. 3d ed. New York, A. T. De La Mare company, inc., 1948. 276 p. il. plates (col.) bibliography: pp. 266-271)

## INSECTS—PESTS

101. The Nearctic leafhopper (Homoptera: Cicadellidae); a generic classification and check list. Paul Wilson Oman. Wash., 1949. 253 p. plates. (Entomological society of Washington. Memoirs. No. 3)
102. A bibliographical supplement to "Coleoptera or beetles east of the Great Plains" (applying particularly to Western United States). J. Gordon Edwards. San Jose, The author, 1950. pp. 183-212. (processed)
103. Pests of flowers and shrubs. G. Fox Wilson. London, H.M. stationery office, 1950. 105 p. figs. plates. (Great Britain. Ministry of agriculture and fisheries. Bulletin no. 97) 2d edition.
104. Orchard insects of the Pacific northwest and their control. E. J. Newcomer. Wash., 1950. 61 p. figs. tabs. (U.S. Department of agriculture. Circular no. 270, revised)
105. The newer insecticides and rodenticides and their use. T. E. McNeel. (Association of food and drug officials of the United States. Quarterly bulletin, vol. XIV, no. 4, October 1950, pp. 142-146)
106. Control of nonsubterranean termites. Thomas E. Snyder. Wash., 1950. 16 p. figs. (U.S. Department of agriculture. Farmers' bulletin no. 2018)
107. New techniques in control of orchard mice. W. Robert Eadie. Ithaca, 1950. 16 p. figs. (Cornell university. Agricultural experiment station. Bulletin 856)
108. A revision of the beetles of the genus Myochrous. Doris Holmes Blake. Wash., U.S. national museum, 1950. 64 p. plates. (U.S. National museum. Proceedings, vol. 101, pp. 1-64, no. 3271)
109. Studies on searching capacity of the larvae of three predators of the citrus red mite. Charles A. Fleschner. Berkeley, 1950. (Hilgardia, vol. 20, no. 13, October, 1950, pp. 233-265)
110. Moths new to Trinidad. Norman Lamont and E. McC. Callan. (Zoologica, vol. 35, part 3, no. 17, pp. 197-207)

## LEGISLATION

111. Guide rural. Paris, Les Editions sociales françaises, v.p. (200 p. approx.) 1948.

## LIVE STOCK

112. Raising livestock. Walter H. Peters and George P. Deyoe. New York, McGraw-Hill book company, inc., 1946. 519 p. figs. tabs.
113. My seventy years with Clydesdales. . . . James Kilpatrick. Glasgow, Henry Munro ltd., 1949. 102 p. il.
114. Pigs. J. W. Reid. London, E. & F. N. Spon, ltd., 1949. 208 p. figs. tabs. (Agricultural series, edited by H. G. Sanders)
115. Ecological animal husbandry research and its application in maintaining a permanent pastoral industry. Jan C. Bonsma. Pretoria, 1949. 23 p. figs. tabs. (South Africa. Department of agriculture. Science bulletin no. 307)
116. L'insemination artificielle. 2e édition. E. Degois. Paris, La maison rustique, 1948. 54 p. il.
117. The beef calf; its growth and development. W. H. Black and E. W. McComas. Wash., 1950. 26 p. figs. (U.S. Department of agriculture. Farmers' bulletin no. 1135)
118. Raising dairy calves. Winnipeg, 1950. 15 p. il. (Manitoba department of agriculture and immigration. Publication no. 236)

## MEDICINE

119. Advances in tuberculosis research. III. Basel and New York, S. Karger, 1950. 307 p. il. (Text in English, French and German) (Supplement to Schweizerische zeitschrift für tuberkulose)
    Editors: H. Birkhäuser, Basel, H. Bloch, New York.
    Contributors: G. Canetti, K. Diehl, H. Good, G. Middlebrook, G. Rocher, F. B. Seibert, E. Suter.
120. Handbook of antibiotics. A. L. Baron and others. New York, Reinhold publishing corporation, 1950. 303 p. Bibliographies throughout text.
121. Recent advances in pharmacology. J. M. Robson and C. A. Keele. London, Churchill, 1950. 418 p. plates, diagrs., tabs. graphs. References at end of chapters.

## METEOROLOGY—PHENOLOGY

122. Results of rainfall observations made in New South Wales, sections I-VI, districts 46-75 . . . 1948. n.p. (1948) 546 p., and appendices, maps. At head of title: Australia. Bureau of meteorology.
123. Rainfall records for Saskatchewan. M. J. Champlin, E. G. Booth, R. O. Bibbey, and C. G. Waywell. Saskatoon, 1950. 31 p. figs. tabs. (Saskatchewan. University. College of agriculture. Agricultural extension bulletin no. 18)
124. Die bedeutung der phanologie für die landwirtschaft. (Importance of phenology for agriculture). F. Rosenkranz. (Austria. Hochschule für bodenkultur in Wien. Jahrbuch, vol. 1, 1947, pt. 2, pp. 57-99)

## MICROSCOPY

125. McClung's handbook of microscopical technique for workers in animal and plant tissues. Edited by Ruth McClung Jones. Third edition, revised and enlarged. New York, Paul B. Hoeber, inc., 1950. 790 p. figs. References through the text.
126. Microtomist's vade-mecum (Bolles Lee), a handbook of the methods of animal and plant microscopic technique. 11th edition. Edited by J. Brontë Gatenby and H. W. Beams. Phila., Blakiston, 1950. 753 p. front. il.

## PHYTOPATHOLOGY

127. The scientific principles of plant protection with special reference to chemical control. Hubert Martin. London, Edward Arnold & co., 385 p. References through the text.
128. The Canadian phytopathological society. Proceedings of the seventeenth session, Charlottetown, 1950. (Ottawa) 1951. 19 p.

## PHYTOPATHOLOGY—Continued

129. Symptoms of cucumber-mosaic and tobacco-ringspot viruses on celery. Henry H. P. Severin. (Hilgardia, vol. 20, October, 1950, no. 14, pp. 267-270) plates.
130. Diseases of tobacco in Canada. L. W. Koch and G. H. Berkeley. Ottawa, 1950. 38 p. figs. (Canada. Department of agriculture. Publication 667. Farmers' bulletin 85, revision)
131. Vegetable protection guide. Assembled by M. E. Neary. Halifax, 1950. 16 p. il. (Nova Scotia. Department of agriculture and marketing. Publication 1015)

## SOILS—SOIL CONSERVATION—RECLAMATION—DRAINAGE, ETC.

132. Procedures for testing soils, sponsored by A.S.T.M. committee D-18 on soils for engineering purposes. Nomenclature and definitions . . . Phila., American society for testing materials, 1950. 418 p. figs. tabs.
133. A water policy for the American people: Report of the President's water resources policy commission. Vol. I. Wash., U.S. govt. printing office, 1950. 445 p. il. tabs.
134. Irrigation principles and practices. Orson W. Israelsen. 2d ed. New York, Wiley, 1950. 405 p. front. (ports.) il. diagrs. tabs. maps. references: pp. 382-396.
135. Soil survey of the Rycroft and Watino sheets. Wm. Odynsky and J. D. Newton. Published by Research council of Alberta, Dominion department of agriculture, and the University of Alberta. Edmonton, 1950. 84 p. figs. maps. (Alberta. University. Bulletin no. 53) (Research council of Alberta. Report no. 56) (Alberta soil survey. Report no. 15)
136. The draining of farm lands. A. W. Hudson and H. G. Hopewell. Palmerston North, 1950. 184 p. figs. (Massey agricultural college. Bulletin no. 18)
137. Land drainage. R. G. Kendall. London, Faber and Faber, ltd., 1950. 133 p. il. figs.
138. The capillary movement of water and salt solutions in soils and other porous media. Stewart Clare. Edmonton, Alberta, 1950. 256 p. (typed)
139. Soil mechanics laboratory manual. Herbert T. Jenkins. Ithaca, Comstock publishing company, 1947. 109 p. (processed)
140. Reconnaissance of ground-water conditions in the Uncompahgre Valley, Colorado. Tom O. Meeks. Albuquerque, New Mexico, 1950. 27 p. figs. tabs. plates. (U.S. Department of agriculture. Soil conservation service. Southwest region. Regional bulletin 112. Geological series 3)
141. Reconnaissance soil survey of Japan, Kyushu area. Robert E. O'Brien and E. J. Kohler. Tokyo, 1950. 73 p. (General headquarters. Supreme commander for the allied powers. Natural resources section. Report no. 110-B)
142. The occurrence of barium in soil and plants. W. O. Robinson and others. Wash., 1950. 35 p. tabs. (U.S. Department of agriculture. Technical bulletin no. 1013)

## TEXTILES

143. Dalgety's annual wool review for Australia and New Zealand, 1949-1950. London, Dalgety and company ltd., 1950. 127 p.
144. World consumption of wool, 1949. London, 1950. 168 p. At head of title: Commonwealth economic committee.

## VETERINARY MEDICINE

145. Animal nutrition and veterinary dietetics. R. G. Linton. 3rd ed. by John T. Abrams. Edinburgh, W. Green & son, limited, 1950. 521 p. plates. References at end of chapters.
146. Veterinary guide for farmers. G. W. Stamm. Chicago, Windsor press, c1950. 288 p. il.
147. Vade-mecum du vétérinaire de H. Mollereau, Ch. Porcher, E. Nicolas. Formulaire vétérinaire de pharmacologie, de thérapeutique et d'hygiène. E. Nicolas et A. Brion. 8me ed. Paris, Vigot frères, 1949. 763 p.
148. United States livestock sanitary association. Proceedings, 1949. Columbus, 1950. 285 p.
149. The 1st report on Japanese equine encephalitis. Government experimental station for animal hygiene. Tokyo, 1949. 203 p. figs. (Experimented report no. 22). (Text in Japanese and English)
150. Effectiveness of penicillin in eliminating mastitis infections in the Bureau of dairy industry herd. W. W. Swett, L. A. Burkey & others. Washington, 1950. 22 p. (United States. Department of agriculture. Technical bulletin no. 1027) Literature cited, p. 22.

NEW PERIODICALS IN LIBRARY:

Food and nutrition. Gt. Britain. Ministry of food. London.
The entomologist's monthly magazine. London.
The journal of pharmacology & experimental therapeutics. Baltimore
Florists' review. Chicago.
Sheep breeder. Columbia, Missouri.

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It might be of interest to readers to know that the following periodicals are among those in the library:

The British fur trade. London.
The British veterinary journal. London.
Report on foreign affairs. Commonwealth parliamentary association. London.
The round table. London.
The Scottish geographical magazine. Edinburgh.
Wool knowledge. London.
The Manx journal of agriculture. Isle of Man. Board of agriculture.
Chimie & industrie. Paris.
Oléagineux; revue générale des corps gras et dérivés. Paris.
Australian journal of agricultural research. East Melbourne.
Australian journal of experimental biology and medical science. Adelaide.
Food technology in Australia. Sydney.
Journal of experimental medicine. Baltimore.
Northwest science. State college of Washington.